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PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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VOLUME 52

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P. D. EDWARDS, EDITOR

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Spring Meeting
MUSCATATUCK STATE PARK
May 22 and 23, 1942

Fifty-Eighth Annual Meeting
NOTRE DAME UNIVERSITY
October 29, 30, and 31, 1942

Copies of the Proceedings may be purchased through the State Library, Indianapolis, Indiana, at $3.00 per volume. All items sent in exchange for the Proceedings and all communications to officers of the Academy, when their names and addresses are not known, should also be sent to the State Library.

Reprints of certain parts of recent volumes of the Proceedings are available for distribution as follows: copies of the constitution and by-laws (Vol. 44), and complete membership list (Vol. 50), may be secured by members elected subsequent to the publication of those volumes; copies of the codified list of duties of officers (Vol. 48) may be secured by officers, divisional chairmen, and chairmen of committees; and copies of the necrology can be supplied to relatives and friends of the deceased members. Inquiries concerning these reprints should be addressed to the Secretary of the Academy, Dr. Winona H. Welch, DePauw University, Greencastle, Indiana.

Reprints of technical papers in recent volumes can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

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OFFICERS AND COMMITTEES FOR 1942

OFFICERS

President, M. G. MELLON, Purdue University.
Vice-President, THEODOR JUST, University of Notre Dame.
Secretary, WINONA H. WELCH, DePauw University.
Treasurer, W. P. MORGAN, Indiana Central College.
Editor, P. D. EDWARDS, Ball State Teachers College.
Press Secretary, C. M. PALMER, Butler University.
Trustees of Academy Foundation: (term 4 years) J. S. WRIGHT, Eli Lilly and Company (term expires 1944), chairman; F. B. WADE, Shortridge High School (term expires 1943).
Committee for Bonding of Trustees: H. L. BRUNER, Butler University, Indianapolis, chairman; W. A. COGSHALL, Indiana University, Bloomington.
Research Grant Committee: A. L. FOLEY, Indiana University (term expires 1941), chairman; E. G. MAHIN, University of Notre Dame (term expires 1942); JOHN S. WRIGHT, Indianapolis (term expires 1943); M. S. MARKLE, Earlham College (term expires 1944); H. E. ENDERS, Purdue University (term expires 1945); M. G. MELLON, Purdue University (ex officio); WINONA H. WELCH, DePauw University (ex officio).

DIVISIONAL CHAIRMEN

Anthropology, C. F. VOEGELIN, Indiana University.
Bacteriology, L. S. MCCLUNG, Indiana University.
Botany, R. C. FRIESNER, Butler University.
Chemistry, K. N. CAMPBELL, University of Notre Dame.
Geology and Geography, G. T. WICKWIRE, Hanover College.
Mathematics, W. E. EDINGTON, DePauw University.
Physics, O. H. SMITH, DePauw University.
Psychology, F. D. BROOKS, DePauw University.
Zoology, T. M. SONNEBORN, Indiana University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

J. C. Arthur,* C. A. Behrens, W. M. Blanchard, F. D. Brooks, H. L. Bruner, S. Burrage, K. N. Campbell, W. A. Cogshall, Stanley Coulter, E. R. Cumings, J. J. Davis, Chas. C. Deam, W. E. Edington, P. D. Edwards, H. E. Enders, A. L. Foley, R. C. Friesner, W. G. Gingery, R. E. Girton, Robert Hessler, Theodor Just, Eli Lilly, M. W. Lyon, Jr.,*

* Deceased since 1941 meeting of the Academy.

E. G. Mahin, E. S. Martin, L. S. McClung, M. G. Mellon, W. P. Morgan, C. M. Palmer, F. Payne, N. E. Pearson, R. R. Ramsey, O. H. Smith, T. M. Sonneborn, C. F. Voegelin, F. B. Wade, F. N Wallace, Paul Weatherwax, Winona H Welch, G. T. Wickwire, J. S. Wright, T. G. Yuncker.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Committee on Relation of Acadamy to State, Program Committee, and Library Committee)

P. D. Edwards, W. G. Gingery, Theodor Just, M. G. Mellon, W. P. Morgan, F. N. Wallace, Winona H. Welch.

STANDING COMMITTEES

(Appointed by the President, Chairman of Each Committee named First)

Auditing: E. S. Martin, K. S. Means.

Biological Survey: N. E. Pearson, W. P. Allyn, H. O. Deay, R. Kriebel, M. W. Lyon, Jr., C. M. Palmer, Dorothy Parker, Winona H. Welch.

Invitations: C. L. Porter, C. A. Malott, J. L. Riebsomer, F. B. Wade.

Junior Academy of Science: H. E. Enders, W. P. Allyn, F. J. Breeze, O. B. Christy, M. S. Markle, M. M. Williams, F. B. Wade, T. G. Yuncker.

Library: W. G. Gingery, Nellie M. Coats, R. C. Friesner.

Membership: R. E. Girton, F. J. Allen, F. V. Graham, Ned Guthrie, G. F. Hennion, Edward Kintner, Naomi Mullendore, J. E. Potzger, R. E. Zirkle.

Nominations: E. G. Mahin, C. A. Behrens, Paul Weatherwax.

Program: Theodor Just, M. W. Lyon, Jr., E. G. Mahin, Scott McCoy.

Publication of Proceedings: P. D. Edwards, R. C. Corley, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, Stanley Coulter, E. Y. Guernsey, Eli Lilly, H. J. Reed, J. S. Wright.

Representative on Council of A.A.A.S.: H. E. Enders.

Resolutions: P. J. Elving, W. Mullison.

MINUTES OF THE SPRING MEETING

MUSCATATUCK STATE PARK, MAY 22, 1942

The meeting was called to order by President Mellon, in the dining room of Muscatatuck Inn, at 9:30 P. M.

Officers and committees reported as follows:

President. Dr. Mellon announced that J. E. Potzger is serving on the Membership Committee in the place of H. H. Nester; and that the committee making the study of the duties of the Research Grant Committee desires more time before making a report. J. J. Davis, Chairman, E. G. Mahin, and Wm. E. Edington compose the committee.

Editor. Dr. Edwards stated that war conditions were retarding the anticipated early publication of the Proceedings.

Fifty-Year Index. A progress report was made by G. H. Smith. Approximately 90% of the manuscript has been delivered to the typist who has completed about 50% of that amount.

Library. Dr. Friesner reported for Miss Nellie Coats. Many new and liberal exchanges have been opened in countries of South America. Approximately $200.00 worth of binding is now in process.

Emeritus Membership. The following were elected to Emeritus Membership: William M. Blanchard, Benjamin H. Grave, Louis J. Rettger, and David A. Rothrock.

Membership. The following were elected to membership in the Academy: William A. Bonner, C. O. Keller, and John D. Mizelle.

Fall Meeting. Because of war conditions it was voted to give power to the Executive Council to decide whether or not the meeting should be held, and if so, whether or not the place should be changed from Notre Dame to a central location such as Indianapolis.

Resolutions. The following resolutions, read by C. L. Porter, were adopted: The Indiana Academy of Science assembled at Muscatatuck State Park, May 22-23, in its Spring Meeting, expresses its appreciation for the hospitality offered by the management of Muscatatuck State Park; for the activities of the program committee under the chairmanship of Theodor Just in arranging field trips and other interesting features of the program; to Ray C. Friesner, Charles C. Deam, Ralph M. Kriebel, C. A. Malott, and C. M. Kirkpatrick for their leadership and kindly council in the various hikes associated with this meeting of the Academy; and for the interest and efficiency demonstrated by the officers of the Academy.

Submitted,
C. L. PORTER, *Chairman.*

Dr. T. G. Yuncker, chairman of Taxonomists' Group, announced that the 1942 foray had been cancelled because of war conditions.

The Academy sent a message to Dean M. L. Fisher, Purdue University, wishing him a speedy recovery from illness.

Adjournment, 10:30 P. M.

Respectfully submitted,
WINONA H. WELCH, *Secretary.*

PROGRAM OF THE WINTER MEETING

UNIVERSITY OF NOTRE DAME

October 29-31, 1942

THURSDAY, OCTOBER 29

7:30 P. M.

Meeting of the Executive Committee

FRIDAY, OCTOBER 30

9:30 A. M. General Session

Address of Welcome. Reverend Hugh O'Donnell, C.S.C., President of the University of Notre Dame.

Response. President M. G. Mellon.

Necrology. Will E. Edington, DePauw University.

"David Dale Owen, Man and Scientist."* Walter B. Hendrickson, MacMurray College, Jacksonville, Illinois.

"Contribution of an Indiana Plant to the War Effort." Lt.-Col. C. Alfred Campbell, Vice-President, Marmon-Herrington Company, Indianapolis.

12:30 P. M. Demonstration of geometrical models

1:00 P. M. Sectional Meetings

6:00 P. M. Annual Dinner

Business session.

President's Address. "Science, Scientists, and Society." President M. G. Mellon, Purdue University.

SATURDAY, OCTOBER 31

9:00 A. M.

Taxonomists Meeting

Junior Academy of Science Meeting and Exhibits

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* The material of this address is being published in Chapter IX of Volume 27 of the Indiana Historical Collections.

MINUTES OF THE EXECUTIVE COMMITTEE

South Bend, October 29, 1942

The Executive Committee was called to order by President Mellon at 7:30 p.m. in the Coral Room of Hotel LaSalle. Minutes of Spring Meeting at Muscatatuck State Park were read and approved. Officers and committee representatives reported as follows:

Academy Trustee. Report of John S. Wright, Frank B. Wade, and W. P. Morgan, Trustees of the Foundation Fund, Indiana Academy of Science for the Year 1941-1942.

Balance from the previous year	$533.36
Total receipts	687.12
Total	$1,220.48
Expenditures	none
Balance (in Indiana National Bank Savings Account)	$1,220.48

Assets in the Fund as of October 17, 1942

Five $1,000 U.S. Savings Bonds, Series D, at cost	$3,750.00
One $1,000 U.S. Savings Bond, Series G, at cost	1,000.00
Federal Farm Loan and Farm Mortgage Bonds at par	2,500.00
One $500 4% U.S. Treasury Bond of '44-'54 at par	500.00
Four $100 4% U.S. Treasury Bonds of '44-'54 at par	400.00
One $100 U.S. Treasury Bond, 4¼% at par	100.00
One $100 U.S. Treasury Bond, 3¼% at par	100.00
One $100 U.S. Treasury Bond, 3⅛% at par	100.00
Two $100 Muncie Masonic Temple Assn. First Mort. Bonds at par	200.00
Six shares Standard Oil Indiana common stock at par	150.00
Total at par or cost	$8,800.00

Report accepted.

Auditing Committee. In the absence of E. S. Martin his signature on the notarized report of the Academy Foundation was accepted as his official report.

Treasurer's Report. Dr. Morgan presented a tentative financial report for the period from January 1 to October 24, 1942. His final report, approved by the Auditing Committee, at the end of the year follows:

Receipts

Balance on hand January 1, 1942	$426.87	
Dues and initiation fees	744.06	
A.A.A.S. refund for research grants	137.50	
Author's reprints Vol. No. 50	33.23	
Author's reprints Vol. No. 51	200.94	
Dr. Parker returned research grant	46.00	
		$1,588.60

Disbursements

1—Program committee	$122.25	
2—Editor	200.00	
3—Expenses of Secretary	28.14	
4—Expenses of Treasurer	65.00	
5—Mailing Proceedings	32.96	
6—Stationery	44.82	
7—Delaware Engraving Co.	136.49	
8—Junior Academy Bulletins	20.00	
9—Bond and Safety Box	31.00	
10—Research grant to Dr. Parker	45.83	
11—Bookwalter Co. reprints	71.87	
12—Balance due for printing Proceedings to C. E. Pauley	6.92	
13—Books purchased for library	4.00	
14—Research grant to Dr. Mullison	50.00	
		$859.28
Balance on hand		729.32
		$1,588.60

(Signed) W. P. MORGAN, *Treasurer.*
(Signed) ERSIE S. MARTIN, *Auditor.*

Bonding Committee. In the absence of Dr. Bruner and Dr. Cogshall, the Secretary read the report which follows:

Enclosed herewith you will find notice of premium due November 18, 1942, on Fidelity Bond No. 1113950, issued by the Hartford Accident and Indemnity Company, in behalf of the Academy of Science. The premium covers the cost of bonds for the following officers of the Academy:

Treasurer bond	$2,000 cost $5.00
One Trustee bond	$5,000 cost 10.00
Second Trustee bond	$5,000 cost 10.00
Total cost	$25.00

The report was accepted and the cost of bonding ordered paid.

Editor and Publication of Proceedings. Dr. Edwards submitted the following report:

Number of copies of Volume 51 of the Proceedings	1,600
Total number of reprints	9,100
Number of pages	316
Total cost of engraving, printing, and binding	$1,485.70
Editorial expense	$200.00

Report was adopted with thanks.

Research Grant. Dr. Foley proposed the following rule: The Research Grant Committee can not consider any application which is not received on or before ten days prior to the meeting of the Executive Committee. Carried.

Dr. Mahin made the following report for the committee on the Study of Duties of Research Grant Committee: The action taken by the Executive Committee at meeting held Nov. 9, 1939, namely, duties 3, 4, and 5 be postponed indefinitely, should be reaffirmed. Adopted.

Biological Survey. The collections and studies on Indiana Bryophytes are being continued by Dr. Winona H. Welch and Dr. Dorothy Parker.

The Committee on Indiana Plant Distribution Records has listed 1200 new county records and 19 varieties and forms previously unreported from the state. A special report is published each year in the Proceedings with intent to keep Deam's Flora up to date. A check list of the Formicidae (Hymenoptera) by R. L. Morris is ready for publication. Mr. Morris is now preparing a paper on the ants which will include descriptions and notes on the distribution and habits of various species. A manuscript on the Noctuidae (Lepidoptera) of Steuben County has been nearly completed by George Ryan of Angola. Work on the Odonata of Indiana is being continued by Dr. B. E. Montgomery of Purdue, aided by Carl Bartholomai. Dr. H. O. Deay of Purdue is continuing his studies on the Hemiptera and Homoptera of the state. Carl Blickenstaff and Frank Skinner are working on the Thysanoptera and Siphonaptera respectively. Report accepted.

Fifty-Year Index. Dr. George H. Smith, the indexer, reported that the 50-year cumulative index for the Proceedings of the Indiana Academy of Science is now in its final stages of completion. The subject index is temporarily assembled into eleven separate sections: Archeology, Bacteriology, Botany, Chemistry, Entomology, Geology, Mathematics, Ornithology, Physics, Psychology, and Zoology. The systematic index includes all genera mentioned in the Proceedings. The third section of the index will be a brief synoptic review of the floristic, faunistic, stratigraphic and geographic data of each of the ninety counties of the state mentioned in the Proceedings. Report accepted.

Library Committee. Miss Nellie M. Coats, Librarian, Indiana Academy of Science Library, prepared the following report for 1941-1942:

In the report for 1940-41 it was noted that letters suggesting the exchange of publications had recently been addressed to 58 scientific and learned institutions and societies in Latin America. As a result of this correspondence 22 new serial titles have been added to the list currently received representing the following countries: Argentina, Brazil, Chile, Costa Rica, Cuba, Haiti, Mexico, Peru, Salvador, Uruguay and Venezuela.

While many foreign societies no longer find it possible to forward publications yet within the last 3 months items have been received from such surrounded or involved regions as Australia, England, Hawaii, Ireland, Portugal, Scotland, South Africa, Switzerland, and Sweden.

It has been suggested by the Smithsonian international exchange service, however, that copies of the I.A.S. Proceedings intended for countries other than Great Britain, South Africa or the countries of the western hemisphere be held until the close of the war, as its exchange shipments to these other countries have been suspended.

During the year the Amos Butler library was purchased for Indiana University. A letter was addressed to Robert Miller, Director of libraries there, calling his attention to the fact that many items in this collection fitted nicely into gaps in the Academy files and Dr. Miller has agreed to keep the Academy in mind whenever the collection is worked upon. For this reason it was thought inadvisable to purchase separate needed items from other sources just now.

One hundred eighty-five volumes were bound this year. Funds will be needed for 200 to 250 volumes next year.

Report was adopted.

Press Secretary. Dr. C. M. Palmer, Press Secretary, submitted the following report:

Through the cooperation of the Publicity Office of Butler University, press releases on the spring meeting and the present fall meeting of the Academy were sent to almost two hundred Indiana newspapers and radio stations. Additional releases were mailed by the press secretary to about fifty college and high school papers in the state. News releases concerning the fall meetings have been sent out, also, by the Publicity Office of the University of Notre Dame.

A special reporter for the Louisville (Ky.) *Times* was present at the spring meeting at Muscatatuck State Park. Several good photographs of scientists in action during their field trips, together with an accompanying article which was more than one-half column long, appeared in the next Saturday and Monday issues of the *Times*.

At the request of the Press Secretary, photographs of most of the officers of the Academy for the present year were received and will be filed at the State Library in Indianapolis with those previously obtained by the former press secretary, W. E. Edington.

Report accepted.

Membership. A progress report was read and accepted and the election postponed until the evening meeting, Oct. 30.

Junior Academy of Science. Dr. Enders reported 38 active Junior clubs in the state, and several have a number of divisions, ranging from two to six. A new club in the Technical High School, Indianapolis, is being nominated for membership.

"The Illinois Academy of Science has loaned to the Indiana Academy of Science two traveling kits; one to serve for the organization of new clubs, and the second, an exhibit of materials upon the subject of Plastics, which may serve as material for presentation of club programs. Dr. Enders purchased a kit from Ross Allen, Ocala, Florida, for circulation among the clubs for program material. It contains preserved venomous snakes, skulls and fangs mounted, together with the anti-venom, and an exhibition of the manner in which it may be used to counteract the bite from venomous snakes."

It was voted to allot $20.00 for the publication, Science Aids Service, and the Treasurer was authorized to pay this amount to the publisher, Louis A. Astell.

Relation of Academy to State. Report of F. N. Wallace was read and accepted. A request has been presented to the State Budget Committee for $1500.00.

Relation of Academy to A.A.A.S. Dr. Enders stressed the necessity of Academy members being members of A.A.A.S., also, in order that increased research funds could be made available for Indiana Academy members. Report accepted.

Invitations. President Mellon appointed C. L. Porter, Chairman, C. A. Malott, J. L. Riebsomer, and F. B. Wade.

Resolutions. President Mellon appointed P. J. Elving, Chairman, and W. Mullison.

Program. Chairman Just presented reasons for some of the sections of the Academy not meeting this year.

New Business. Dr. Behrens presented the wish of the Indiana Branch of the Society of American Bacteriologists to affiliate with the Bacteriology Section of the Academy. Dr. Yuncker moved that a committee be appointed to study this request of affiliation and be instructed to report at the Spring Meeting of the Academy. Carried.

Dr. Bruner and Dr. Cogshall were elected to continue as the members of the Committee for Bonding Trustees.

Dr. Mahin was elected to succeed himself on Research Grant Committee, his new term expiring in 1947.

Dr. Mahin moved that papers in the hands of chairmen at proper time, from sections not meeting, be considered as eligible for publication. Carried.

Adjournment, 10:45 p.m.

MINUTES OF THE GENERAL SESSION

University of Notre Dame, October 30, 1942

Reverend Hugh O'Donnell, C.S.C., President of the University of Notre Dame welcomed the Indiana Academy of Science to the campus. President Mellon responded in behalf of the Academy.

The necrology prepared by Dr. Edington was read.

Minutes of the Executive Committee meeting of October 29, 1942, were read by the secretary and approved by the Academy.

Dr. Foley reported that W. R. Mullison, Purdue University, had been granted $100 from A.A.A.S. through the Academy for his research problem, The determination of the gross effects of supplying nitrogen in the form of urea to plants deficient in certain of the necessary elements as contrasted with those appearing when these deficient plants are supplied with nitrates.

Two addresses followed: "David Dale Owen, man and scientist", by Walter B. Hendrickson, MacMurray College, and "Contribution of an Indiana plant to the war effort", by Lt.-Col. C. Alfred Campbell, Indianapolis.

Following the dinner in the Bronzewood room, Hotel LaSalle, Dr. R. E. Girton presented forty-two applications for membership, including one Junior Academy Membership, making a total of forty-eight applications for the year. The secretary was instructed to cast an unanimous ballot for the forty-eight applicants.

Dr. Mahin read the nominations of the committee as follows: President, Theodor Just, University of Notre Dame; Vice-President, C. L. Porter, Purdue University; Secretary, Winona H. Welch, DePauw University; Treasurer, W. P. Morgan, Indiana Central College; Editor, P. D. Edwards, Ball State Teachers College; and Press Secretary, C. M. Palmer, Butler University. The nominees were elected.

The Divisional Chairmen elected in the sectional meetings for 1943 were announced as follows: Anthropology, G. K. Neumann, Indiana University; Bacteriology, L. S. McClung, Indiana University; Botany, A. T. Guard, Purdue University; Chemistry, E. Hughes, Eli Lilly & Company; Geology and Geography, W. T. Buckley, Indiana University; Mathematics, W. E. Edington, DePauw University; Physics, O. H. Smith, DePauw University; Psychology, W. A. Kerr, R.C.A., Indianapolis; and Zoology, R. M. Cable, Purdue University.

Dr. C. L. Porter announced that the Committee on Invitations had selected Indianapolis for the 1943 Fall Meeting of the Academy.

The Resolutions Committee expressed, on behalf of the Academy, its sincere appreciation for the hospitality offered by the University of Notre Dame and its members, and for the careful preparation made by

the Program Committee under the leadership of Professor Just. The report was accepted.

Dr. M. G. Mellon, retiring president, delivered a very interesting address on the subject, "Science, scientists, and society".

The 58th annual meeting of the Indiana Academy of Science, with a general attendance of 113 and a dinner attendance of 68, was adjourned.

WINONA H. WELCH, *Secretary.*

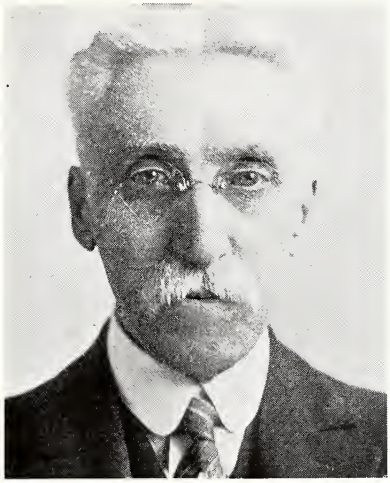
NECROLOGY

Will E. Edington, DePauw University

Joseph Charles Arthur

Lowville, New York — Brook, Indiana
January 11, 1850 — April 30, 1942

Joseph Charles Arthur was one of Indiana's most distinguished scientists. Blessed with a long and active life, he early attained and maintained a leading place among the botanists of the United States, and became an international authority in his chosen field of research, the Uredinales, or plant rust fungi. At the time of his death he was the only member of the Purdue Faculty, and one of the very few Indiana scientists, ever elected to membership in the American Philosophical Society.



Dr. Arthur was born in New York but at the age of six years he moved to Iowa with his parents. He entered Iowa State College at its opening in 1869 and was a member of its first graduating class in 1872. This was the era of the founding of land grant colleges, and preceded the organization of agricultural experiment stations and state and national departments of agriculture as we now know them. Few colleges and universities then had well organized departments of botany. At Iowa State Dr. Arthur worked under Dr. Charles E. Bessey who directed his interests to applied botany which became his life's work. In his senior year at Iowa State he joined the American Association for the Advancement of Science, which at that time had a membership of 610, and

throughout the rest of his life he was active in its work and at the time of his passing he had held membership longer than any one else in the organization. In 1877 Dr. Arthur received the M.S. degree at Iowa State, and later continued his studies at Johns Hopkins, Harvard and Cornell universities, and in 1886 he received the first doctor's degree in science conferred by Cornell University.

As early as 1876 Dr. Arthur showed unusual ability in scientific research and won a major award for physiological apparatus exhibited at the Philadelphia Centennial Exposition. From 1879 to 1882 he taught botany at the Universities of Minnesota and Wisconsin, and in 1884 he was appointed research botanist at the newly founded Agricultural Experiment Station at Geneva, New York, being the first person in the United States to hold such a position. Here he performed pioneer scientific work on pear blight and other plant diseases which brought him national recognition. However, he had already begun his research on plant rusts before going to Geneva and had published the first of his 146 papers in that field in 1882. His last paper appeared fifty-four years later, in 1936. He came to Purdue University in 1887 as Professor of Botany, and in 1888 became the first Botanist in the Purdue Agricultural Experiment Station. He served as Head of the Department of Botany until his retirement in 1915 as Emeritus Professor of Botany, but he continued his research studies at the University and maintained close relations with Purdue until a few years before his death.

While Dr. Arthur's principal research dealt with rust fungi, he nevertheless did notable work in more general fields. He was one of the first to demonstrate that bacteria could cause diseases of plants, and his work with formaldehyde in the control of potato scab was of unusual scientific and economic importance. Also he continued his designs of physiological apparatus and received awards at the Columbian Exposition in 1893 and at the Century of Progress Exposition in 1932. Besides his numerous published research papers and memoirs, Dr. Arthur was joint author with Charles Reid Barnes and John M. Coulter of the celebrated ABC book on botany *Hand-Book of Plant Dissection*, joint author with D. T. MacDougall of *Living Plants and Their Properties*, and with a number of associates of volume seven of the *North American Flora* and *The Plant Rusts*. He was sole author of a *Manual of Rusts in the United States and Canada*. It is also of interest to note that Dr. Arthur in 1897 directed the thesis with the title "The Curvature of Roots," by Dr. D. T. MacDougall, for the first Doctor of Philosophy degree ever given at Purdue. Dr. Arthur taught only for a few years but nevertheless he trained a number of men in his laboratory who have become prominent botanists and plant physiologists. In his studies of the rusts he built up a herbarium containing over 60,000 specimens which is rich in type collections, culture material, notes, drawings and photographs. This herbarium is now the property of Purdue University and is known as the Arthur Herbarium. Because of his outstanding achievements the University of Iowa conferred the LL.D. on him in 1916, Iowa State College the Sc.D. in 1920, and Purdue the Sc.D. in 1931.

Dr. Arthur was well known personally to most of the botanists in this country and Europe. He spoke at the International Congress of Arts and Sciences at St. Louis in 1904, and he was a delegate to the International Congresses of Botanists that met in Vienna in 1905, in Brussels in 1910, and in Cambridge in 1930. In 1925 he made a special trip to Europe to confer with mycologists who were especially interested in rusts and he visited botanists in Germany, Sweden, Norway, Switzerland, and England. He was also active in various scientific organizations. In the American Association for the Advancement of Science he was secretary of section F in 1886, assistant general secretary in 1887, and a vice-president in 1895, a Fellow in 1883, and an emeritus life member in 1924. He was twice president of the Botanical Society of America, and president of the American Phytopathological Society. He also held memberships in a number of other American and foreign societies.

Dr. Arthur was a charter member of the Indiana Academy of Science and was its president in 1893. Throughout the greater part of his fifty-five years of residence in Indiana he was active in the work of the Academy and appeared numerous times on its programs. He was present at the Fiftieth Anniversary Meeting in 1934 in Indianapolis as an honored charter member of the Academy, and at the Purdue Meeting in 1938 both he and his long distinguished colleague Stanley Coulter were paid special tribute on the Academy program. The name of Joseph Charles Arthur now takes its place with the names of those other illustrious Hoosier scientists, David Starr Jordan, John C. Branner, Barton W. Evermann, John M. Coulter, Thomas C. Mendenhall, William A. Noyes, Willis S. Blatchley, and others, who brought honor and distinction to Indiana and the Academy of Science.

EDMUND SMITH CONKLIN

New Britain, Connecticut — Bloomington, Indiana
April 19, 1884 — October 6, 1942

In 1934 Indiana University was seeking a head for its Department of Psychology and the choice was finally settled on Edmund Smith Conklin, one of America's leading psychologists, and a scientist noted for his research techniques and as a stimulator of research. Dr. Conklin came to Indiana from the University of Oregon where he had spent twenty-three years, first as an Assistant Professor of Psychology for two years and then as Professor and Head of the Department. He served also as acting dean of the Graduate School in 1922-1923.

Dr. Conklin graduated in 1908 from the Springfield, Massachusetts, Y.M.C.A. College and immediately entered Clark University. He received the master's degree in 1909 and then became a Fellow in Psychology and received the Ph.D. degree in 1911. That fall he went to the University of Oregon. In 1939 Clark University conferred the Sc.D. degree on him. Dr. Conklin served at various times as visiting professor at the University of Chicago and during his last summer at Syracuse University.

Dr. Conklin wrote numerous papers and monographs on genetic and abnormal psychology that stimulated much research. He was also the author of *Principles of Abnormal Psychology*, 1927; *Psychology of Religious Adjustment*, 1929; *Principles of Adolescent Psychology*, 1935; and he was joint author with F. S. Freeman, of Cornell University, of *Psychology for Students of Education*, 1939. He was also a member of the Editorial Board of the *Journal of Genetic Psychology, Genetic Psychology Monographs*, and the *Psychological Record*.

A Fellow of the American Association for the Advancement of Science and a member of the American Psychological Association, Dr. Conklin served as a representative of the latter organization on the National Research Council from 1939 to 1941. In 1938-1939 he was president of the Midwestern Psychological Association. He became active in the Indiana Academy of Science shortly after coming to Indiana University and he presented papers and served as chairman of the Psychology Division.

Dr. Conklin possessed a very pleasing and genial personality and was an excellent teacher, being concise and especially effective in his illustrative methods. His health became impaired about two years before his death but he continued his teaching duties until the end. His passing at the comparatively early age of fifty-eight years represents a real and distinct loss to science both in the state and the nation.

OLAF HOVDA

Dane County, Wisconsin — Henderson, Kentucky
September 6, 1874 — September 7, 1942

With the death of Dr. Olaf Hovda, Evansville College lost the last member of the original Faculty which greeted its first students in 1919. An ardent devotee of golf he was stricken with a fatal heart attack while playing his favorite game.

Dr. Hovda was born in southern Wisconsin, of Norwegian parentage, and received his early education in a one-room country school. Later his family moved to Duluth, Minnesota, where he was enabled to do his preparatory college work so that he could enter the University of Minnesota. In 1904 he received the bachelor's degree with Phi Beta Kappa honors, mathematics and physics being his special interest. After teaching for several years in Fairmont, Minnesota, high school he returned to the University of Minnesota as an assistant in mathematics and physics and received the master's degree in 1911. He immediately went to Germany to study at the University of Göttingen where in 1913 the Ph.D. degree was conferred upon him.

Upon his return to the United States he became an instructor in mathematics at the University of Iowa, but in 1915 he went to Morningside College as Head of the Department of Mathematics and Physics where he remained three years. Following a year of teaching at Carleton College, he came in 1919 to Evansville College as Head of the Department of Mathematics and Physics.

Dr. Hovda was the author of several research papers in physics but he preferred teaching to research. His teaching was characterized by considerable originality, for he possessed considerable inventive ability. He constructed much valuable apparatus such as a wind tunnel for the study of model airplanes in his aviation course, and he supervised the construction by his students of a miniature planetarium. He had been an instructor in CAA courses during his last three years. An inspiring teacher, and popular with both students and alumni, he was made honor guest at the annual alumni banquet two years before his death. He was also very well known around Evansville and advised and cooperated with a civic group in working out plans for smoke control.

He was a member of Phi Beta Kappa and Sigma Xi. He was a Fellow of the American Physical Society and a member of the American Association of Physics Teachers and the Indiana Society of Physics Teachers. Dr. Hovda regularly attended the meetings of the Academy. His death is a distinct loss to Evansville College and the Academy of Science.

JESSE G. LISTON

Clay County, Indiana
May 2, 1870

Clay County, Indiana
July 8, 1941

Jesse G. Liston was a teacher for forty years in the district schools of his home county. He was descended from a long line of pioneers, his paternal great grandfather having been a scout in William Henry Harrison's army and having plowed the first furrow in the wilderness where Terre Haute now stands. Another great grandfather was a Baptist minister who helped to establish what is now Louisville Seminary in Kentucky. After receiving his preliminary education in the public schools of his community, Mr. Liston entered Cooper College, now Sterling College, Sterling, Kansas, where he completed the four-year Normal Course. He then returned home and began his life's work.

Always deeply interested in the science of geology he became an authority on the geological formations of Clay and adjoining counties. He knew and had records of the formations in every drill hole and rock outcrop, and even of most of the wells, for a radius of thirty or forty miles from his home. He knew the coal strata and he built up a detailed stratigraphic sequence of the formations in his section of the state. He was frequently consulted by geologists who were interested in his region of southwestern Indiana. He was a studious and widely read man.

But Jesse G. Liston was first of all a teacher and he loved his pupils who were represented often by several generations in the same family. Somewhat quiet and reserved, he was nevertheless a kindly, friendly, lovable man who held the esteem and highest respect of his friends and neighbors. On his retirement from teaching more than six hundred of his former patrons and pupils gathered at his home to do him honor, and he received hundreds of greetings from former pupils in half the states of the Union.

While not a scientist in the professional sense of the word, nevertheless Mr. Liston made a distinct contribution to science through his

example and influence on the lives of others, and the Academy could well profit from the interest and support of others like him who pursue science as a hobby.

MARCUS WARD LYON, JR.

Rock Island Arsenal, Illinois — South Bend, Indiana
February 5, 1875 — May 19, 1942

The success and prestige attained by any organization depends very largely on the caliber of the men and women it attracts to its membership. The Indiana Academy of Science has been very fortunate in this respect, for it has had at all times active in its work a group of members with national and international reputations. To the younger scientists the contacts with these mature and recognized scientists are invaluable and the Academy program may well be a training and proving ground for the beginner in research, for the criticisms and approval of these prominent members is a fine preparation for the national scientific forum. And in one's scientific association with Marcus Ward Lyon, Jr., one was working with such a man of high scholarly and scientific achievement who was zealous for the truth and impatient with anything less than one's best efforts. Dr. Lyon was one of the most broadly trained men in the Academy, for he was equally at home in zoology, botany or medicine, and his published research ranged over mammology, bacteriology, parasitology, pathology and botany, and he was professionally a zoologist, bacteriologist and pathologist.

Marcus Ward Lyon, Jr., was the son of an army captain and his boyhood was spent around army posts. Following his graduation from Rock Island High School in 1893 he entered Brown University and received the Ph.B. degree in 1897. He taught bacteriology for one year in North Carolina Medical College and then went to Washington, D.C., as Aid in the Division of Mammals, U.S. National Museum. He was made Assistant Curator in 1907, which position he held until 1912. In 1899 he and Lieutenant Wirt Robinson were sent by the Museum to collect mammals in Venezuela, and in 1904 he was appointed Chief Special Agent for the U.S. National Museum for the Louisiana Purchase Exposition in St. Louis, and in 1905 for the Lewis and Clark Exposition in Portland, Oregon. A trip to Europe in 1911 enabled him to visit the principal museums there and to become acquainted with many of the leading zoologists of Europe. His work at the Museum was so arranged as to allow him to carry on his graduate studies at George Washington University, which conferred on him the M.S. degree in 1900, the M.D. in 1902 and the Ph.D. in 1913. He also taught physiology in the Medical School of Howard University in 1903-1904 and again from 1907 to 1909, after which he taught bacteriology for six years and then bacteriology and pathology from 1915 to 1917. The next year was spent in teaching veterinary zoology and parasitology in the George Washington University Medical School. The years 1917 to 1919 he served in the U.S. Army as pathologist at the Walter Reid General Hospital, attaining the rank of Major in the Medical Reserve Corps in 1919. In 1919 he and his wife,

who was also a physician, joined the South Bend Clinic where he remained as pathologist until his death.

Dr. Lyon was an ardent naturalist and nothing pleased him more than to study nature first hand. When permitted freedom from museum and laboratory duties he went into the field to gather specimens or to study birds and animals in their natural habitat. He made extensive zoological and botanical collections. His zoological collections are now in the U.S. National Museum, and the U.S. National Herbarium, Smithsonian Institution, and the University of Michigan Herbarium each possess extensive botanical collections that Dr. Lyon made. His principal zoological interest was mammals, both living and prehistoric, and one of his deepest regrets was that the State of Indiana possessed no suitable museum for housing the prehistoric finds made in the State. He was an authority on mammalia and he was one of the collaborators on *Nomenclator animalium generum et subgenerum* being published by the Prussian Academy of Sciences in Berlin. He was also author of a book *Mammals of Indiana*. But Dr. Lyon was primarily a physician and among his 160 papers on biological and medical subjects are many reports on unusual or interesting cases that passed through the clinic. These appear in the *Journal of the American Medical Society*, *Journal of the Indiana Medical Association*, and other medical journals.

Dr. Lyon maintained numerous scientific affiliations. He was a Fellow of the American Association for the Advancement of Science, an Associate of the Ornithological Union, and a past president of the American Society of Mammalogists. He held membership in national societies of bacteriologists, ecologists, parasitologists, and pathologists, as well as in national and state medical societies, and the American Chemical Society. He was also a member of Phi Beta Kappa and Sigma Xi. Dr. Lyon was very active in the Indiana Academy of Science and served as treasurer from 1927 to 1932 and as president in 1933. He frequently presented papers and actively supported its conservation efforts. Keen and witty, his friendly and wise comments, suggestions and influence were always welcome at Academy meetings, and his loss will be deeply felt in Indiana scietific and medical circles.

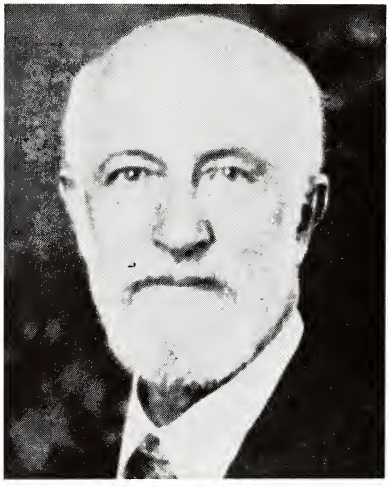
ARTHUR JOHN PHINNEY

Geauga County, Ohio — Franklin, Indiana
August 29, 1850 — May 26, 1942

Arthur John Phinney was a charter member of the Indiana Academy of Science, but he had not been active in the Academy for many years. However, he was present at the Fiftieth Anniversary Meeting in 1934 and spoke at the banquet. Until his retirement on account of his age he had been a practicing physician for thirty-two years, twenty-seven of which were spent in Muncie, Indiana.

Dr. Phinney was born on a farm twenty miles east of Cleveland, Ohio, and he received his early education in a country school and in the high school and academy of a neighboring village. He then attended Oberlin College for one year and Allegheny College for two years after

which he taught school for six years. In 1875 he entered the Western Reserve University Medical School and later graduated with the M.D. degree in 1877 from Pulte Medical School, Cincinnati, Ohio. However, being deeply interested in botany he began working on the flora of Ohio and Indiana and gathered specimens of flowering plants, rushes, sages, grasses and ferns. His list of nearly one thousand species was published in the *Report of the Indiana Geological Survey for 1882.* He joined the Indiana Geological Survey under State Geologist John Collet and made surveys of Delaware, Randolph, Grant, Rush, and part of Wayne counties, the results of which appear in the *Reports* for 1882 to 1885.



The last work was done under Maurice Thompson, who was then State Geologist. Becoming interested in the discoveries of gas in Ohio and Indiana, Dr. Phinney made careful study of the geology of the fields which led to his employment by the U.S. Geological Survey. The results of these studies were published in the *Eleventh Annual Report of the U.S. Geological Survey.* Later Dr. Phinney took up medical practice in Muncie, Indiana, which he followed until his retirement.

Dr. Phinney was widely read and deeply interested in the origin and evolution of religious beliefs, in the origin of the American Indian, whom he believed to be due to a cross of the black and brown man, and the great problems of irrigation of parts of the western American deserts. He had written some 1,200 pages of manuscript which a few years ago he hoped to have published. A deeply earnest man of firm convictions, his last years of a long, interesting and worthwhile life were spent in the Masonic Home at Franklin, Indiana.

PRESIDENTIAL ADDRESS

Science, Scientists, and Society

M. G. Mellon, Purdue University

The subject selected for this address—science, scientists, and society—is indeed formidable, at least to any group assembled for an occasion such as this. On the one hand, the range is nearly limitless; and, on the other hand, time and the ability of the speaker are definitely limited. Then, too, triteness is a handicap, for often equivalent subjects must have served many a commencement speaker needing a non-committal title for his remarks.

Nevertheless, the choice was made deliberately, since previous addresses by chemists before this Academy have all been very general in nature. Formulas and equations, the chemist's indispensable form of sign-writing, have been almost entirely avoided. In following this precedent it seemed wise to reject as possible subjects various aspects of analytical chemistry, my principal field of research. In a more positive direction, the choice was made because of a feeling that what is most fundamental in science for a chemist is equally fundamental for other scientists. Whatever interest the discussion may have, therefore, should be general.

The Problem

Many years of teaching and research have aroused a personal desire to know, as far as possible, the essence of the scientific activity to which most of us are devoting our lives. Just what is science? Is it a kind of religion, sufficient in itself as a way of life in modern society? If all were trained in science, would we be able to live together happily thereafter? Possibly what I have in mind may be clearer in the form of another question—What does science mean to me? Obviously, the answer to be proposed is entirely personal. My only justification for presuming to present it is the hope that each of you, if you have not already done so, will make a similar effort to answer the question yourself. Like John Dewey, most of us must feel some urge to pursue such a quest for certainty. One's answer reflects his attitude as a scientist.

These broad aspects and implications of science seem to have little interest for the average scientist and technologist. Busy with their respective activities, they transmit tradition, pigeon-hole facts, theorize about them, and apply them in a thousand ways. Although the total effect of these activities during the last two centuries has been profound, both on our daily lives and on our thinking, only occasionally have writers tried to evaluate the really basic contribtions of science and scientists to society, and to focus their possibilities on the future.

Such evaluations as have been made range from high praise to disparagement. The former is represented by the predictions of A. H. Compton and of J. D. Bernal that science can remake the world, and by the assertion of W. B. Pitkin that scientists are the only ones today who have anything worth saying. For the latter we may mention the book, *Science the False Messiah* by C. E. Ayres, and the statement of Vice-President Henry A. Wallace that science, during the last 100 years, has merely increased the speed of life without increasing its quality.

President R. M. Hutchins of the University of Chicago, a prominent student of educational trends, has questioned the whole social potentiality of science. Excerpts from his addresses are quoted.

"The sciences at best," he says, "may help us attain our ends if we knew what those ends were; . . . but we do not know where we are going or why, and we have almost given up the attempt to find out. We are in despair because the keys which were to open the gates of heaven have let us into a larger but more oppressive prison house. We think those keys were science and the free intelligence of men. They have failed us. Many have long since cast off God. To what end can we now appeal? The answer comes in the undiluted animalism of D. H. Lawrence, in the emotionalism of demagogues, in Hitler's scream, 'We think with our blood.'

"The centrifugal forces released through the dissolution of ultimate beliefs," he continues, "have split the universities into a thousand fragments. These institutions, instead of leading us through the modern world, mirror its confusion. . . . We are in the midst of a great moral, intellectual, and spiritual crisis. To pass it successfully or to build the world after it is over, we shall have to get clear about those ends and ideals which are the first principles of human life and of organized society. Our people should be able to look to the universities for the moral courage, the intellectual clarity, and the spiritual elevation needed to guide and uphold them in this critical hour. . . . Research is not enough either to hold the university together or to give direction to bewildered humanity. We must now seek not knowledge but wisdom."

In re-examining science for its essence there is this year, as never before, more than satisfaction of mere curiosity to be considered. Involvement in another world war, threatening our very civilization, makes especially urgent the question of what permanent help we may expect from science. We need to transend our specialties to gain a balanced perspective of just what science is, and is not, in contemporary life.

Most scientists would probably agree that science represents primarily an extension of knowledge. Presumably such accumulated information is expected to accrue to the benefit of mankind, for people have long been told that the truth would make them free. Thus, in theory at least, it would seem that science should serve society in some constructive way.

By itself, and through innumerable practical applications, science has been, in fact, of untold benefit to us. We know more about the material universe, and we are better able to control it, than any preceding

generation. All this is, or could be, for the general good. Such information and activity are potentially constructive in helping us to meet the ceaseless succession of events constituting the cosmological drama. That knowledge is power has become a proverb of the race. The scientist and technologist appeared in the scene only recently; but so significant have been the results that often we hear the present period referred to as the age of science.

Unfortunately, science, especially in its applications, does not necessarily contribute to the general welfare. As a result, many individuals have been, and some still are, critical of our work. Lavoisier, the greatest chemist of the 18th century, was beheaded with the curt comment that France needed no scientists. Recently holidays for research have been advocated, presumably in the hope of reducing technological unemployment thereby. The year 1942 finds us in the midst of the most devastating war in history, one whose unparalleled destruction is possible only because of scientific knowledge.

We are faced, then, with a great paradox of constructive versus destructive possibilities and actualities. I shall attempt to examine the relation of science and scientists to human affairs in the hope that an orientation of our perspective may aid in making dominant the constructive potentialities of science. Also we shall note what science does not, and probably cannot, do. In the time available it will be possible to indicate only in broad outline what seem to be the most important aspects of this problem.

Science and Its Accomplishments

Science may be defined as knowledge which has been systematized with reference to the discovery of general truths or the operation of general laws. The process of assembling, organizing, and applying this knowledge has long been under way. For centuries the rate of progress was very slow; but in recent decades it has been so accelerated that today the civilized world is relatively aware of the larger subdivisions of science, such as biology, chemistry, geology, and physics.

For the present purpose our interest is not in the minutiae of any of these subjects. What seem important are the items that may be considered as a kind of scientific common denominator. Long contemplation of what these are has led to the conclusion that all science, theoretical and applied, can be reduced to two categories—facts and their interpretations. It will now be necessary to examine each of these categories more at length. Subsequently, attention will be directed to the procedure of science, the scientific method, including its motivation and application.

I. **Facts.** Science begins with facts and facts form its body. These units of funded experience and knowledge are its basic truths.

A. S. Eddington has referred to facts as being often primarily meter readings. Yet we must have many of them, for they are the basis of understanding and of intelligent action in the modern physical world. For example, the uninformed might eat cyanide, but only once, of course. Constituting the principal portion of the descriptive material in sciences

such as biology, chemistry, and geology, facts represent our observational records. In addition, they serve as the foundation of all applied science. Through invention they yield new machines, processes, compositions of matter, and biological plants.

Incidentally, in spite of their obvious importance, facts may be over-emphasized in teaching. We instructors may be largely responsible for the development in certain students of a near-allergy for the sciences. These subjects, instead of being a thrilling intellectual awakening to such students, mean chiefly the memorization of endless bare facts, to be parrotted back to the instructor and then to be promptly forgotten. As stated by a novelist, the subject is treated as a "corpse which bit by bit we painfully dissect."

Facts should be definite and unquestionable. Also it is highly desirable to have them demonstrable in order to make later verification possible in case of doubt. Indeed, some consider that in science a fact must be mechanically demonstrable to be true.

There are, however, many conflicts over facts, for scientific observation is often subject to illusion and error. Thus most people state that the sun rises in the east and sets in the west, but it does neither. Frequently facts are difficult to obtain, and there may be disagreement as to what they are. One needs only to mention such problems as prohibition of alcoholic liquors, the economic depression of 1932, or one's chances for immortality without baptismal immersion to illustrate the confusion that may prevail. For these troublesome cases Glenn Frank advised that, "all the remedies for all the types of conflicts are alike in that they begin by finding the facts rather than by starting a fight."

"The recording of facts," according to the late Justice O. W. Holmes, "is one of the tasks of science, one of the steps toward truth; but it is not the whole of science. There are one-story intellects, two-story intellects, and three-story intellects with sky lights. All fact collectors, who have no aim beyond their facts, are one-story men."

Mere collections of facts do not make science, any more than a pile of stones makes a house. The facts must be systematized, according to suitable criteria, to constitute scientific knowledge. This classification process is really only an extension of the description process of fact collecting.

Chemistry presents two striking examples of classification. The compounds of carbon are arranged in the monumental treatise of Beilstein according to classes. The 4,877 types projected about the year 1900 have been found adequate for the third of a million organic compounds now known. The compounds of the other 91 elements are discussed in inorganic treatises primarily according to families, as found in Mendeleef's famous periodic table. Without such organization, the countless facts covered in either case would be largely useless.

Finally, it should be noted that facts, in and of themselves, do not move us to do anything with them. For instance, how many, even among scientists, act on the basis of the known facts of genetics, when they select the parent for their prospective children? Neither more facts, nor

wider dissemination of those we already possess, will alone be sufficient to improve society.

II. Interpretation of Facts. The poet Noyes visualized the next step in his statement, "Day after day the slow sure records grow, awaiting their interpreters." Such are the multi-story men of Justice Holmes. "Two-story men," said he, "compare, reason, and generalize, using the labors of the fact collectors as well as their own. Three-story men idealize, imagine, and predict. Their best illumination comes from above, through the sky light."

Interpretation of facts consists, then, of finding relationships and formulating generalizations. The facts are the basis for conclusions, reached by induction. One may distinguish between the process followed and the products obtained.

1. **The Process.** The first step in any interpretation is to study the facts, both individually and collectively. After they are subjected to scrutiny from all feasible view points, possible or probable conclusions are proposed. Finally, we formulate tentative generalizations or plans of action.

Many would maintain that this operation consists in explaining the facts. We should note, however, that one does not explain phenomena in any final sense. Science merely locates things and their actions in space and time. It does not indicate what finally makes them act or why they are. This means, according to C. E. Ayres, "that science never solves the mysteries of the forces which rule our lives."

According to H. Poincaré, the mathematician, science cannot teach us the nature of things—only their relations. Science "explains" a phenomenon, the effect, by showing that it is a necessary, or probable, consequence of another phenomenon, the cause. As R. W. Emerson said, "the effect already blooms in the cause." Over-zealous teachers, in asking for explanations of phenomena, run the risk of developing in their students an unjustified feeling of finality in this respect. At best, with Shakespeare's soothsayer, one can state, "In Nature's infinite book of secrecy a little can I read."

If we have difficulty agreeing upon the facts which bear on a given problem, it is little wonder that different people may interpret a given set of facts differently. The development of science has seen the rise and fall of many an interpretation. One of the most famous examples in chemistry was the phlogiston theory of combustion, advocated for more than a century by all the famous chemists of the time but now recognized as a totally erroneous concept.

2. **The Products.** The results of generalization, whenever the process is carried far enough, may be recognized in one of three forms. These are so well known that they need little more than mention here.

An hypothesis is the least definite of the interpretations. It is not much more than a tentative assumption regarding possible cause-effect relations, an intelligent guess about the how of things.

A theory may be considered as a more or less matured hypothesis. It has advanced far enough toward certainty to be subject to experimental verification. It must be open to modification as long as experiments do not support the necessary conclusions. A theory is the working plan of projected experiments, such as the enterprise of the Tennessee Valley Authority.

A law is a generalized statement of the order or relation of phenomena. A law of nature, of course, explains nothing; it is only a descriptive formula which states what things do. In it isolated fact-descriptions are given a generalized description form. Even then few laws are more than approximations, for they generally rest upon statistical probability.

III. **The Scientific Method.** Our vast stock of facts, and of interpretations in the form of theories and laws, combined with myriad technological applications based upon them, represent a truly remarkable achievement of the human race. The material contributions of the last two centuries far exceed all similar prior progress. Such extensive accomplishments merit consideration of their cause.

Many factors must have been operative; but probably it would be conceded that objective experimentation and impartial thinking, more than anything else, are responsible. In fact, A. N. Whitehead has stated that, "the greatest invention of the 19th century was the invention of the method of invention." In the words of E. C. Wickenden, "progress no longer waits on genius or the occasional lucky thought—instead we have learned to put our faith in the organized efforts of ordinary men." Our great industrial research laboratories are striking evidence of this faith.

This process, which has proved so fruitful, is known as the scientific method. Briefly, it involves collecting the facts, sorting or classifying them, formulating conclusions therefrom, and, if possible, subjecting these to experimental verification. Publication of the results usually follows with academic scientists. Perhaps the most succinct statement of the process ever made is that of Glenn Frank, a non-scientist. In his words, "our concern with the facts is to (1) find them, (2) filter them, (3) focus them, and (4) face them."

In discussing progress in his book, *The Mind in the Making,* J. H. Robinson outlined four principal types of thinking. (1) We day-dream—an activity to be observed among one's students, or possibly one's colleagues. (2) We make routine decisions—often a necessary activity; for example, one has to select items at a cafeteria counter. (3) We defend our prejudices—an activity in which we really begin to show some zest, especially if the subject in question is economic, political, religious, or social, and if we have been suitably conditioned in early life. How much time and energy have been wasted here! (4) We think creatively—an activity Professor Robinson ranked low in quantity. Its quality, however, is about the only hope the race has for material progress. The great performers in this category are Holmes' three-story men—the Newtons, the Darwins, and the Einsteins.

With scientists this creative thinking involves the scientific method. Its effectiveness depends upon obtaining the facts without resort to

authority, and upon reasoning with an unprejudiced mind. The most important result of science teaching, according to scientists, would be achievement of this self-elimination in forming judgments. The significance of this attitude of mind can not be over-emphasized. Probably the basic test of a scientist is his sincerity toward the scientific method.

The extent of our factual knowledge, and of its technical applications, would seem to be ample evidence of the worth of this method. Nearly every science teacher extols its merits, and he would vigorously affirm that his first teaching objective is to inculcate his students with this process of thinking, to be used not only in the specific subject studied but also in everyday problems. To illustrate its industrial effectiveness he may point to the fact that chemical research laboratories of the United States have produced more than 200,000 products since 1914.

Limitations of Science and Scientists

With this record of achievement, represented by an immeasurable extension and application of knowledge, using a process of proven worth, who could be dissatisfied? Yet discerning readers and critical observers have expressed disappointment in the total results. Thus, according to Vice-President Wallace, himself a scientist, the last century of science has not improved the quality of society, although science yields annually an ever greater stream of truth.

The present state of society and the attitude of men toward each other, after two centuries of contact with modern science, make one wonder. Is there any basis for adverse criticism? If weakness exists, can anything be done about it? Or have we simply been misled to expect too much?

Since the scientific method has been so effective in obtaining truth about the physical world, many have assumed that this effectiveness insures application of the process, at least by scientists and those trained in science, to focus this truth on our daily problems. If one is shown the way, it is only reasonable to assume that he will follow it. Such complacency, however, is destined for disillusionment. Once again, the process consists in finding, filtering, focusing, and facing the facts. Obviously, this is merely a logical sequence of actions. What is lacking is motivation for action. There is nothing inherent in the method either to make one want to get the truth or to act upon it if and when obtained. How many chemists, for example, to say nothing of the thousands who have studied chemistry incidentally, try to live according to the best knowledge of physiological chemistry? We know well enough the way to normal weight and sobriety; but the obese and the alcoholic continue with us. We need, as Glenn Frank stated, a fifth step—following the facts. Even this would not provide the initial urge to get them.

H. G. Deming, a chemist, must have sensed this limitation when he wrote, "science is but a feeble means for motivating life. It enlightens men, but fails to arouse them to deeds of self-sacrifice and devotion. . . . It dispels ignorance, but it never launched a crusade. It gives aid in the struggle with the hard surroundings of life, but it does not inform us to what end we struggle, or whether the struggle is worth while. . . . Intelligence can do little more than direct."

This lack of motivation in the scientific method, combined with the mental inertia of the ordinary habit-laden individual and the emotional inertness of facts, undoubtedly accounts largely for what we find on surveying the extent of adoption of the process by scientists for general use and by the educated public.

Most reputable scientists are likely to conform to the method reasonably well in their specialties, particularly if the work is to be published. It is well known, however, that even eminent men may show little more than the prejudices established by early conditioning when they presume to discuss topics outside their own specialties. In fact, it is not common to find scientists who can be generally trusted for scientific soundness of judgment on non-scientific subjects. Winning a famous scientific prize, or holding an important position, gives no assurance that the individual's opinions on economic, political, religious, or social questions have any considered factual basis. This abandonment of the scientific method by many scientists, when they close the doors of their laboratories, reminds one of pseudo-religionists who go to church on Sunday and then grab all they can on Monday. A man's veneer of scientific attitude must be thick to prevent his thus easily reverting to the prejudices of youth.

The so-called educated public gives us even less reason for optimism. President N. M. Butler of Columbia University has stated the case in an annual report, from which quotation is made.

"For two generations," he wrote, "a very considerable part, perhaps a major part, of the effort of educational systems and institutions has been expended upon the development of teaching and research in the natural and experimental sciences. . . . The essential fact in all scientific study is the use and the comprehension of the scientific method. Every conclusion as it is reached is held subject to verification, modification, or overthrow by later inquiry or by the discovery of new methods and processes of research.

"One would suppose," he continued, "that after half a century of this experience and this discipline the popular mind would bear some traces of the influence of the scientific method, and that it would be guided by that method, at least in part, in reaching results and in formulating policies in social and political life. If there be any evidence of such effort, it is certainly not easy to find. Passion, prejudice, unreason still sway men precisely as if scientific method had never been heard of. How is it possible, with all the enormous advances of science and with all its literally stupendous achievements, that it has produced such negligible results on the mass temperament and the mass mind? This is a question that may well give us pause, for something must be lacking if intelligent men and women, long brought into contact with scientific method and scientific processes, pay no attention whatever to these and show no effect of their influence, when making private or public judgments."

If we teachers are producing only partially scientific scientists, and almost entirely non-scientific laymen, what is the reason? Probably foremost is our own incomplete exemplification of the scientific attitude. We can hope to justify the method to others only as we believe in and practice it generally ourselves, irrespective of the possible personal

rewards or costs. To the extent that expediency makes us disloyal to this ideal, we foster the cynical, widespread suspicion that every man has his price. It is hardly necessary, of course, to note that attempting to be scientific in everyday life and to follow one's conclusions may take courage, as more than one scientist can testify. Stuart Chase has analyzed this problem most effectively in an article entitled "The Luxury of Integrity."

Although more truly scientific teachers and leaders would help, another fundamental obstacle is our current conception of success. We are motivated, with too few exceptions, by dollars and things rather than by ideals of understanding and of humanitarian service. For measuring accomplishment the popular standard is income in industry and number of publications in college teaching. Thus despoilers of the nation's natural resources are likely to be honored as great business men, if they become rich, while the discoverer of a fundamental law of nature may go hungry. "If there is a fatal weakness in American society," writes A. H. Compton, "it is the lack of (enduring) objective." But, undaunted by the idolatry of the material, Lewis Mumford, new head of Leland Stanford's School of Humanities, still thinks the ultimate problem of a university is one of values rather than publications and patents.

Consideration of this diverse motivation, ranging from the idealistic to the materialistic, may help us to understand something of the social actions of scientists, and of technologists who use science.

Those directing their efforts toward idealistic goals are attempting first of all to understand the facts, as far as possible. Individuals with curiosity long to learn about man and his world. How does the firefly produce his light? What causes the succession of the seasons? Why do some people have red hair, or in later life have left on their head little of any hue? These and a thousand like questions crowd the mind of anyone alert to his physical environment. The thinking man has the capacity, and likes, to understand things.

To achieve the highest good, this individual aims not only to understand the facts, but also, in the light of them, to make that adjustment to his physical environment, including his fellow men, which will promote the general welfare. To him, knowledge of nature means both admiration for its laws and an effort to conform to them. A famous chemist, Justus Liebig, recognizing the ideality possible in this direction, stated that science to such individuals is a goddess to worship.

Although few people would object to a better understanding of facts, evidently what is most often sought of science is facts to use, whether they are understood or not. Control of their environment, by means of applied science, seems to be the goal of the majority of scientists and users of science. Thus, the chemist makes synthetics, the metallurgist alloys, the physicist radioactive atoms, and the geneticist new organisms.

To what purpose is all the latter activity directed? Why are our research and development laboratories, numbering more than 2,000 in the United States alone, spending many millions of dollars annually to get new facts and make new products? Primarily the urge is to survive

or to gain personal or group advantage. The individual strives to make some discovery, usually in order to reap financial or other personal reward, rather than to improve the lot of humanity. The great corporation aims to keep in advance of competitors; real competition spurs ingenuity, discovery, and invention. Something of the extent of such activity is revealed by the announcement each Tuesday of approximately 1,000 new United States patents.

Liebig must have felt this materiality when he completed his statement about science by noting that to many individuals it is merely a cow to milk. Among the milkers one finds the whole collection of self-seekers, the most offensive of whom use science chiefly as a means for accomplishing their selfish objectives. Here, unfortunately, are the acquisitive, the egotistic, the expedient, the insincere, the dictatorial, the ruthless, and the dishonest—in short, the little Hitlers of science. To this group may be traced most of the distrust and discord so often found among academic and industrial scientists. What a change in personal relationships, and consequently in science, would result if these people were to practice the Golden Rule.

Viewed from the standpoint of the possibility of improving society, these limitations may be summarized as (1) emotional inertness of science, (2) lack of motivation in the scientific method, and (3) low social consciousness of many of those trained in science. As for the first two, we must resign ourselves to the inevitable—they are facts. Any hope of improvement, therefore, must center in the human element. A. A. Berle, Assistant Secretary of State, used these words: "the techniques of modern life—our engineering, chemistry, and medicine—are only tools. In and of themselves they do nothing; what they achieve arises from the desires of men's minds."

The Future of Science

What of the future? In such troubled times as these prophecy is extraordinarily uncertain, for no one can foretell the results of the social and political forces now loose. Science might become restricted to implementing the repressive tyranny of those in power. In suggesting other possibilities, we are assuming that no such regimentation awaits it.

With the return of reasonable sanity and stability in social and political life, it seems safe to predict that science will continue in the general direction taken during the last few decades. More facts will be discovered, technological applications, perhaps undreamed of today, will be found for many of them, and new theories and laws will be formulated. The scientific method will work in the future, as it has in the past.

But need this be all? Some scientists, at least, do not think so. Since science has revealed so much about things, from coal tar to the stars, and since it has shown how to operate successfully, these men think that economic, political, and social problems should be susceptible to such treatment. Indicative of this trend is the formation of the Committee on Science and Society of the American Association for the Advancement of Science. Recently its chairman, L. K. Frank, wrote, "if we are to have a social order directed by intelligence and guided by scientific

knowledge . . . scientists must take a more active role in focusing scientific study and helping to direct the application of their findings." In similar vein, G. H. Boyd has stated, "the task of implanting the aim, the spirit, and the method of science in the minds and the activities of the public is one of the important tasks which science and industry must face."

Much as the social order seems to need such attention, it is not clear that the men quoted realize the limitations of science. We must keep in mind that it provides only means and a method. There seems little probability, judging by the past, that science will itself make men more socially minded. Such motivation must originate in ways beyond the scope of this address. According to C. E. Ayres, "science is completely impotent to determine what had better happen. . . . The only attitude toward human struggles appropriate to modern science is serene indifference, the indifference of the dynamo or the mechanical calculator."

In considering what lies ahead, therefore, account must be taken of human possibilities and aspirations. The scientific method undoubtedly can be applied in areas now little touched, even though the process may be more difficult than in the physical sciences. Also there is certainly no reason why it cannot be followed more conscientiously by all scientists outside their specialties, and by those whose education has included an introduction to science. The question is whether they want to do it, and whether they are able as individuals to surmount the type of educational conditioning which causes a scientist to react in ways illustrated by his voting a straight ticket because his grandfather did.

In an ever-changing world man constantly confronts problems. Current examples are the physically and mentally unfit, distribution of wealth, conservation of natural resources, and war. Although we could well use many specific contributions, such as a disease-resistant chestnut tree or a cure for cancer, the larger problems are more pressing. There is needed a long-time program based upon collective, planned action rather than rugged individualism. The latter alternative is admirable in theory, to the extent that one practicing it may develop much latent ability; but general adherence to this principle would bring results such as unrestricted reproduction of the mentally defective, waste and destruction of natural resources, and general practice of might makes right. Application of science and the scientific method, actuated by adequate social motivation, seems a much more promising approach.

Assuming that scientists of the future become motivated to do something, and that they have the opportunity, how would they attack a problem? The following steps seem obvious: (1) get the facts bearing upon it; (2) study it in the light of these facts; (3) choose a tentative solution which seems likely to work best; and (4) make tests to determine if this prospective solution does work. If it does not, modify the method or select another and try again; that is, resort to the pragmatic test of workability by following the biblical admonition to "Prove all things and hold fast to that which is good."

Some famous scientists, advocating such practice, have expressed the belief that the presence of more of their number in, or close to,

economic and political life would greatly facilitate the alleviation of our economic and social problems. In accordance with the Platonian vision of a society led by reliably informed rulers, the suggestion is to have a non-political, permanent group of investigators to provide information for administrators on possible and desirable courses of action. Such boards, if sincere and socially motivated, could provide information and programs; but for success of the plan the administrators would still have to want, and dare, to apply the knowledge in order to achieve what E. Stanley Jones has called a welfare economy.

The London *Times*, in reporting a conference on science and world order, stated recently, "But though science shows the way, it would be presumptuous to believe that science alone can lead us to the goal. The men of science themselves have moved far since the era of uncritical optimism, when progress was regarded as automatic and science as its predestined instrument. We need no evidence today that science can serve evil ends as well as good. . . . This is no reproach to the instrument, but a reminder that the ultimate test of its value lies in the moral purpose directing it. The most important service rendered by the conference has been to bring to public knowledge the almost unlimited potentialities of human development and human well-being which science has to offer. Science provides the opportunity. There must be the will to use it."

Conclusion

What, then, does science mean to me? The answer includes elements of admiration, disillusionment, and faith.

In essence, science represents an unbelievably large collection of facts, and interpretations of these facts, relating to every known area of the natural world. Acquisition of this information, and application of it in the arts and industry, are the glory of the scientific method.

Science and the scientific method are primarily human tools. They provide information and means for action; but they do not suffice in themselves to make anyone act, or, in case of action, to direct it to human good. The latter ends, if we want them, necessitate transformation and direction of our motivation by other means.

The scientific approach is the most effective procedure thus far discovered for enabling us to understand, and to adjust ourselves to, the physical world. In doing this we may well turn to Glen Frank for our motto. "Let's stop being radicals or conservatives," he said, "and be scientists. That is, let's act in the light of the facts in the case, rather than in the (twi)light of our prejudices or the faded labels of our class, our clique, or our clan."

Contribution of an Indiana Manufacturing Plant to the War Effort*

C. Alfred Campbell, Marmon-Herrington Company, Indianapolis

The military emergency in which we now find ourselves is of course interfering with formal education from many angles, but I do not feel that there is any question about the fact that it is increasing the importance of and stimulating the interest in scientific subjects, which is all to the good. Our peacetime life had become a life of science. Modern warfare is even more dependent upon you gentlemen.

While I have this opportunity to speak to you as educators, as well as scientists, there are a couple of points regarding our national polity which I would like to present. I cannot feel that there is any incongruity in asking your consideration of these broader aspects of education. There has of course been a constant divergence between the arts and the sciences. With the great increase in the sum total of human knowledge, brought to us by science, a high degree of specialization has become necessary. However, I feel that a rapprochement between science and philosophy has set in. The very methods of teaching a philosophical or arts subject in themselves constitute a science.

The fathers of our country were scientists as well as philosophers. Benjamin Franklin was a physicist of no mean ability. During the framing of the Declaration of Independence Thomas Jefferson carried in his handbag some fossilized bones of the Megalonyx, which now bears his name.

Seriously, I should like to invite your thought to the situation which confronts our nation. The general state of physical and psychological unpreparedness in which we found ourselves on the seventh of last December should serve as a lesson to us. Following the first World War we allowed ourselves to become physically and mentally soft. For a period of twenty-two years we have been a nation of international lotus eaters. Beginning now, let us face realities, let us steel ourselves to the part we have to play, not only for the duration, but for the peace to come. This, the most charitable and altruistic nation on earth, should not again lapse into indifference and impotence.

The educational institutions of the nation should devote more time to teaching the American Way of Life, as such. Every student should learn to know our constitution better and to respect it more. To back up our way of life and our constitution, units of the R.O.T.C. should be established in every high school and college. I also feel that during the last two years of high school and for four years in college, compulsory, rigorous physical training programs should be adopted. What we really need is a course of strenuous physical development for every student,

* Presented before the general meeting.

which will harden him for the future problems he must face, be they personal or those of his nation.

In his introduction to a new edition of Tolstoy's "War and Peace," Clifton Fadiman observes that the German military mind seems to be incapable of making any mistakes except the very biggest ones.

In World War I, the biggest mistake of the German military mind was its underestimation of America's strength. Even when it appeared certain that the United States would become one of the Allied Nations, the meticulous planners of the Imperial German High Command remained positive that America's part in the war would not change the balance. That the great weakness in America's armor lurked in this nation's total dependence upon Germany's chemical industry, the Germans well knew. In one of his last reports to Berlin, a German envoy commented on this weakness and confidently predicted our defeat as a result.

"Americans," he said, "can never establish such an industry. The conflicting selfishness of American business renders it impossible."

But American scientists responded to the nation's need and, pushing aside the "conflicting selfishness" in which the enemy placed his trust, built in the United States the world's greatest chemical industry.

The big mistake of the thorough German mind was then, the same as it is now. Once more our enemies have overlooked the potential power of America's secret weapon.

This weapon is, of course, that *voluntary cooperation of free people* which converted the American wilderness into a giant among nations. It has been overlooked by the Axis because it could neither be known, nor understood, nor used in totalitarian countries.

Americans have always recognized the power of this weapon. The pioneers in the wilderness used it in their log rollings (and I don't mean political), in their barn raisings, their corn-husking bees, and in the organization of their wagon trains when they penetrated farther across the existing frontier.

Although mutual helpfulness is the basis of many American traditions, we tend to forget how powerful an instrument this practice can be until we stand in great peril.

In 1940, after the fall of the Low Countries and France, it first became evident to many Americans that such a time of great peril was impending.

All of the nations conquered by Hitler had gone down crying "Give us airplanes."

In Washington, at that time, General Arnold was insisting that our air forces should be equipped with fleets of heavy bombers. Many of the military leaders of the world were skeptical. But General Arnold stuck to his guns and convinced enough people to get his proposal authorized.

To those working on the program, then termed the National Defense Program, it was plain that the American aircraft industry would have to have help—especially if we were to expect heavy bombers on time and in big enough quantities to mean anything. That help, national leaders felt, would have to come from the automobile industry.

So, on October 25, 1940, just two years ago last Sunday, Mr. Knudsen went to Detroit to ask the automobile and truck and parts manufacturers for their help.

The result of that meeting was the organization of the Automotive Committee for Air Defense, in which the so-called "conflicting selfishness of American business" was set aside to give way to mutual helpfulness in building bombers. The aircraft manufacturers opened their doors wide to the engineers and master mechanics of the automotive industry, and, in due time, the lessons were mastered and production started.

By March of 1941 it was possible to disband the Automotive Committee for Air Defense. In the production of aircraft, America's secret weapon—voluntary cooperation—was unsheathed.

Then, last December, came the Pearl Harbor attack, followed by our imperilled nation's demands for more and ever more of all kinds of weapons.

On the day after Christmas a letter from an Army Air Corps officer was received by the directors of the Automobile Manufacturers Association. It pointed out how well mutual helpfulness of former competitors was working in the production of aircraft, and suggested that the idea might now be expanded to embrace all arms manufacture in the automotive industry.

A few hours before the year 1941 ended, they had set up the machinery for this voluntary cooperation. They called it the **Automotive Council for War Production.**

That Council has now come to embrace more than 400 manufacturers who are pulling together in teamwork for victory. Their cooperation has become the pattern of other industries.

The greatest strength of this secret weapon is that it generates power progressively—the more we draw upon it for strength, the more powerful it becomes.

Just as many of the horrors of modern warfare are the unwanted children of science and research, the modern blitzkrieg is the lineal descendant of the horseless carriage. It is therefore quite fitting that the automotive industry should thus be called upon to strain every sinew toward the production of airplanes, military vehicles and combat tanks, as well as to contribute a considerable proportion of the other necessary articles of ordnance.

The average person little realized that this is a war of horsepower. In 1918 the average infantry division was equipped with 3,300 horsepower. Today's armored division musters 400,000 horsepower.

Horsepower on wheels and wings is what the United Nations need most. It is also what the United States can produce best and fastest.

"When Adolf Hitler put his army on wheels," says General Somervell, chief of the U. S. Army Services of Supply, "he drove right down our alley."

It is estimated that the horsepower potential of internal combustion engines produced by one automotive manufacturer alone in 1941 is 100 times the 2,400,000 horsepower generated by the Grand Coulee Dam.

The cavalry no longer rides horses, but armored cars. The infantry no longer walks, but rides. In the artillery, guns, limbers and crews are hauled by trucks, not horses. And so on down the line. In addition to the cars and trucks for the transportation of personnel and material, numberless highly specialized vehicles have been designed to meet specific needs, and play minor, but significant roles in military movement.

There are, for example, the big trucks, "mobile class-rooms" used for training army officers in truck mechanics at various camps across the nation. Each truck contains various types of engines, transmissions, axle assemblies and other vital parts of motor trucks.

Another valuable development is the rolling lubratorium. Built to travel up to 50 miles an hour over hard-surfaced roads, it can perform in the field any lubricating job that can be done in the shop.

Since glasses are now worn by about 15 per cent of the men in the armed forces, the army recently produced a motorized solution to the problem of what do do when glasses are broken. It is a truck-borne optical shop which carries $20,000 worth of lenses, frames, blanks, grinders, etc. It can repair the spectacles of an army of 300,000 on the battlefield.

The first field office trailer to be used in the army was created last year. It boasts a build-in desk, work table, map board, and typewriter stand. Electric lights and telephone facilities can be had by plugging in on the service lines covering the maneuver area. It can be packed and on the move in less than five minutes when a division is suddenly forced to change its position.

A special service truck has been built to carry bombs from arsenal to plane. Rigged with derrick and windlass, it hauls a trailer loaded with bombs which weigh as much as 1,200 pounds each.

A portable laundry unit able to take care of the weekly laundry of about 1,500 soldiers has been developed by the Quartermaster Corps. Mounted on a four-wheel semi-trailer, it contains all the machinery required to do field laundering. Laundry companies to operate these units consist of 153 enlisted men and five officers. Each company has 10 units to operate, and is thus able to serve about 15,000 soldiers in the field.

Also accompanying troops into the field is a new mobile sales commissary or post exchange to sell cigarettes, candy, razor blades and about 60 other articles. Mounted on a 2½-ton truck, the unit carries a driver, four clerks and a stock of goods sufficient to supply about 8,000 men.

The army's recruiting service has also taken to wheels. Trucks and trailers—18 in number—were put into operation to reach localities where there are no established recruiting stations. From its complete equipment and information service, it can give the prospective recruit all he needs to know of the army he is about to join, its opportunities and classifications.

Of all the new and unusual vehicles which have been developed by the automotive industry to increase the effectiveness of our armed forces, the one which has completely captured the public fancy and has added

a new word to our language is the "Jeep." Technically, it is a quarter ton, 4 x 4, open bodied, four passenger, personnel carrier or towing unit.

Practically it is the pullingest vehicle for its size ever invented. The soldier's pride and the sophomores' envy.

It will pull through desert sand, wade through mud up to its axles, or literally climb the side of a mountain, as surefooted and tough and dependable as a pack mule.

The real secret of the jeep's performance is the fact that the motive power is applied through all four wheels.

All-wheel-drive, or the application of motive power to all wheels, is not new. It antedates the first World War, and our Army in France had different makes of trucks which were thus propelled and they gave a good account of themselves, though their number was relatively small and they had their faults of design and construction.

The transportation problems which confronted our army in the first World War were manifold and Mr. A. W. Herrington, chairman of the board of our company, who was a captain in the Motor Transport Corps, had ample opportunity to observe them from the seamy side. He is one of those rare, gruff personalities who combine something of the genius with bulldog tenacity and an entrepreneurial instinct. He came back from the A.E.F. with the idea that something ought to be done about it.

For ten or twelve years he worked with various truck companies and as consulting engineer with the U. S. Army and the U. S. Marine Corps.

In 1931 with Mr. Walter C. Marmon he formed the Marmon-Herrington Company. If America can rightly claim to be the Arsenal of Democracy, the Marmon-Herrington Company can well claim to be the laboratory of that arsenal.

From the inception of the company until the present time our engineers have designed, on our own responsibility, all manners and types of military vehicles which are now being produced in quantities by the mass production manufacturers. Armored cars, scout cars, aviation crash trucks, artillery tractors, balloon winches, prime movers. The prototypes of a large percentage of current American military vehicles were designed and built in the Marmon-Herrington plant.

These past years have been an interesting period with our company. America had not been preparedness minded and while the various using services have been interested in our developments, appropriations for purchases in commercial quantities have been lacking. Up until the beginning of the war, our revenue has accordingly been largely from the adaptation of these same all-wheel-drive, all-terrain vehicles to highly specialized commercial uses.

The basic precept of all of our truck engineering is all-wheel-drive. Of course we adapt the wheel and tire equipment to the type of terrain and work involved. We supply additional speeds or gear ratios to increase the available torque, but the chief secret of performance is the additional traction due to having power applied through all wheels.

Early in the company's history, Marmon-Herrington equipment made

a name for itself in hauling pipe for the Iraq Petroleum Company in the construction of the oil line from Kirkuk to Haifa and Beyrouth across the Syrian Desert. In difficult transportation problems throughout the world our equipment is cutting time and saving money. Logging in California, in the oil fields of Louisiana, Colombia or Arabia, mining in Bolivia, plowing snow in North Dakota, or fighting mosquitoes in the marshes of northern Illinois.

From the human interest side, this breadth of distribution in the commercial end of our business, as well as our dealings with most of the United Nations on military equipment, has brought a kaleidoscopic parade of interesting nationalities to our factory door.

To us as prospects, customers, inspectors, or students, have come Latin Americans, Chinese, Persians, Siamese, all manner of Europeans and Britishers from such widely scattered parts of the empire that we have had to learn to say not only tomātoes and tomätoes, but also tomătoes.

At least partly for linguistic reasons, somewhat the same sort of an interesting succession of personalities has crossed the threshold of my own home. As a result my fourteen-year-old son not only does not know a stranger, but hardly recognizes the fact that there is such a thing as a foreigner. He is an average high school student, but to watch the development of his global (to use a word of recent popularity) perspective has been interesting.

When he was three years old we had a little girl two years old next door who chattered incessantly, but no one could distinguish a word she was saying. One day Mrs. Campbell saw him talking to the little girl across the low hedge, for a long time. She wondered if he really could make anything out of what the little neighbor was saying. When he came in she asked if they had had a good visit and he said yes. Then she asked what Marylinda had to say, and he said, "I don't know, she speaks Spanish."

Our commercial export business led to nice orders for foreign military equipment. More recently we have had contracts from our own country for considerable quantities of war materials. However, we are still relatively small producers and our total amount of finished material, impressive as it is, is but a minor fraction of our government's needs.

Our big contribution to the war effort is in the ideas and pilot models which we have developed on our own initiative and delivered to the government. Our units have served for the experimental tests and as patterns for the mass producers.

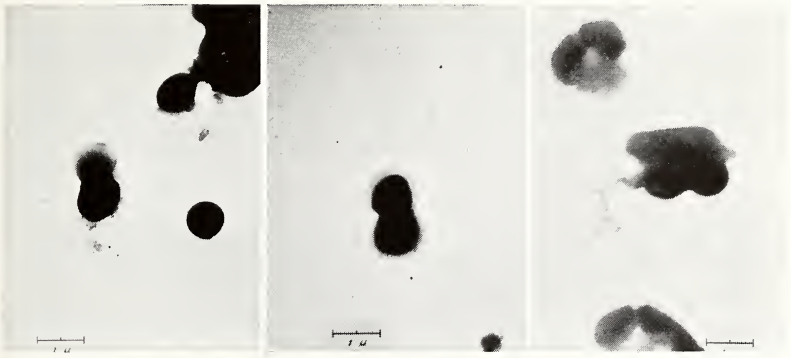
One of our proudest claims to distinction is that the almost phenomenal "Jeep" is the recognizable lineal descendant of our Marmon-Herrington All-Wheel-Drive Converted Ford Pickup.

Gentlemen, I wish to thank you for this opportunity to be with you. I hope that you have enjoyed this little glimpse over our back fence as much as I have. And now just one more thought. The winning of the war and the orderly development of the peace to come lie to a large extent in the lap of you men of science.

Electron Micrographs of Bacteria Medicated with Penicillin

LUCILE J. WEISS, Lilly Research Laboratories

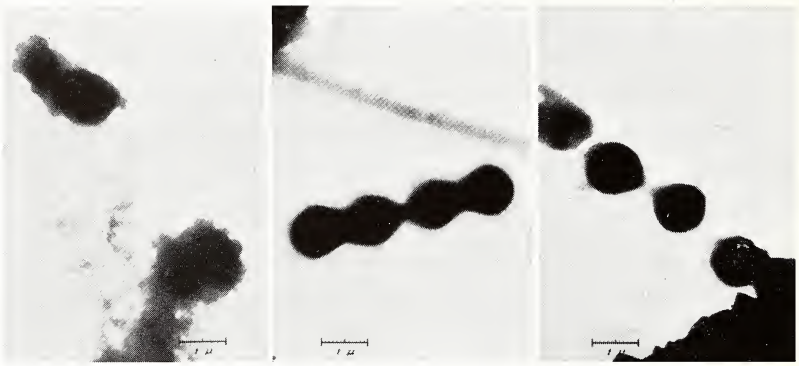
Introduction. A voluminous literature attests the interest of bacteriologists in all kinds of substances having antiseptic action. These substances might, for convenience, be classified as "chemical" and "biological." The chemical antiseptics include the well-known commercial antiseptics, including, in the last decade, the sulfonamides. The relatively enormous literature on this subject need not be considered here. The biological antiseptics, on the other hand, include bacteriophage; gramicidin and its allies; and penicillin and similar substances. Mechanism of action and visible effects on vulnerable bacteria have been dealt with in the case of bacteriophage (1) and gramicidin (2) but not thus far with penicillin.



This report concerns the appearance of bacteria, as revealed by micrographs taken with the electron miscroscope, with and without medication with penicillin. The penicillin used in this study was that referred to by Powell and Jamieson (3, 4). The cultures used comprised *Staphylococcus aureus* No. 209, obtained from the Food and Drug Administration, (5) *Streptococcus hemolyticus* C-203, commonly used in this country for experimental chemotherapy, and *Clostridium welchii*, obtained from the Antitoxin Laboratories of this company.

Experimental. All tests of action of penicillin were of the usual bacteriostatic type, including inoculation of one standard loop of live culture into culture media containing varying dilutions of penicillin and incubated at 37° C. for 8 to 48 hours. All cultures were grown in appropriate broth media, centrifuged, the supernatant fluid removed, and the bacteria resuspended in saline solution. A drop of this suspention was then placed on the small screen disc holding the usual collodion film. On drying, the disc was placed in the specimen holder and introduced into the evacuated chamber of the electron miscroscope.

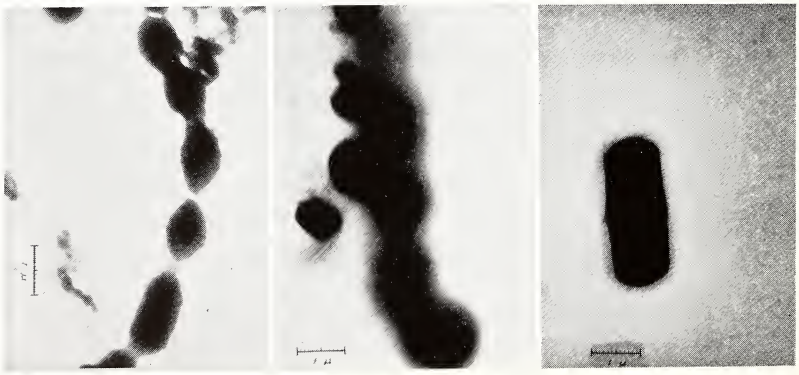
The micrographs in all instances show normal and medicated bacteria subjected to electron miscroscope magnification of 6,000 times and then photographically enlarged to 21,000 times. In most cases, the best micrographs of medicated bacteria were made from the strongest dilution of penicillin plus culture in which there was some visible bacterial growth present. Many observations showed the penicillin-medicated bacteria as greatly enlarged, and in many cases fission was incomplete and long chains of organisms were observed.



Figures 1 and 2 show untreated *Staphylococcus aureus* No. 209 grown in broth and subsequently washed to remove extraneous material clinging to the cells. Figures 3 and 4 show the same strain of Staphylococcus following medication with penicillin. In Figure 3 the cell in the upper left hand corner appears to be extruding cellular substance.

Figures 5 and 6 show untreated *Streptococcus hemolyticus* C-203 as grown in broth and prepared as described above. Figures 7 and 8 show the same strain of Streptococcus medicated with penicillin. The greatly increased size of the cells may be noted, and also the cell walls of many organisms appear irregular and ragged.

Figures 9 and 10 show 48-hour cultures of *Clostridium welchii* unmedicated and medicated, respectively, with penicillin. The medicated



organisms appear at this time quite regularly in filaments and chains, and in nearly all instances the separate cells in the chains are scarcely distinguishable.

Discussion. In the last couple of years, penicillin has attained considerable importance because of its in-vitro and in-vivo antibacterial action. As a "biological" antiseptic, tested in vivo, it appears to fulfill the necessary criteria of a truly chemotherapeutic substance considerably better than gramicidin, which in turn shows more promise in this respect than bacteriophage. Attention has been called to the great number of reports dealing with the first two of these biological antiseptics, namely bacteriophage and gramicidin. These studies include data on such critical properties as specificity, potency, mode of action, and also visible effects produced on medicated organisms.

In this report an attempt has been made to examine the visible effects, if any, which penicillin produces on vulnerable bacteria, using for this purpose suitable electron micrographs. Such pictures appear to show that penicillin does not cause lysis of medicated bacteria (as does the bacteriophage) but on the other hand inhibits or kills vulnerable bacteria, following which minor cellular changes, including enlargement (hypertrophy?) as indicated above, may follow. In this respect, the action of penicillin resembles that of gramicidin or even that of the sulfonamides, in which visible cellular changes are not so profound as in bacteriophagy.

In concluding, I want to thank Mr. W. A. Jamieson, Dr. H. M. Powell, and Dr. J. M. McGuire for making this paper possible and for their cooperation and advice.

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Rapid Pertussis Agglutination Tests of the Blood of One Hundred Normal Adult Persons

H. M. Powell and W. A. Jamieson, Lilly Research Laboratories

Introduction. During the past year we have been concerned with blood typing and luetic flocculation tests of many thousands of bloods from persons acting as plasma donors. Following completion of these two tests, a sample tube containing blood clot, left-over serum, and more or less loose red blood cells about the clot is ordinarily discarded. It appeared of interest to conduct rapid pertussis agglutination tests with a series of samples of these serum plus red blood cell mixtures (adjusted roughly to simulate whole blood in appearance) in order to determine the incidence of pertussis agglutinins by this technique in normal healthy adults. This report gives the results of these tests of one hundred persons, blood samples of which were selected at random.

Materials Used. The antigen used was a blue colored pertussis suspension described by Powell and Jamieson (1) and adapted to the performance of rapid agglutination tests in which a single drop of antigen is mixed with a single drop of blood or blood serum on a slide or piece of impermeable cardboard. Results of preliminary tests with this antigen have already been reported (2, 3). Most of these tests have been conducted with the blood or blood serum of experimentally vaccinated laboratory animals. Daughtry-Denmark (4) and Lapin, (5) however, have published favorable preliminary results of the use of this rapid test in connection with examination of blood and blood serum from children vaccinated against pertussis. More recently Dr. John J. Miller, Jr., (6) has informed us of similar results which he has obtained.

The blood samples used in the tests reported in this paper were those referred to in the introduction. These were obtained from healthy adult persons who acted as donors of plasma for military use. These persons comprised both sexes between the ages of 21 and 60 years and at the time of bleeding showed hemoglobin of 80 per cent or more, temperature not to exceed 99.5° F., and presented satisfactory clinical evidence of freedom from malaria, tuberculosis and heart trouble, and general freedom from illness during the preceding month. (7) Their pertussis history was undetermined.

The rapid pertussis agglutination tests herein reported were conducted as already described. (1) This procedure comprises placing a droplet of blue pertussis antigen in this case on a piece of glazed cardboard of the size of a microscope slide or smaller, and adding to this a similar droplet of blood from the various blood samples utilized. The combined drop is stirred a few seconds to form a circle of one-half to three-quarters inch in diameter, and following this the cardboard slide is tilted back and forth for a period of one minute in order to insure

thorough mixing of antigen and blood. At the end of this time, the test drops are set aside to dry and, on drying, readings of the degree of agglutination are assigned them, after which they may form a permanent record.

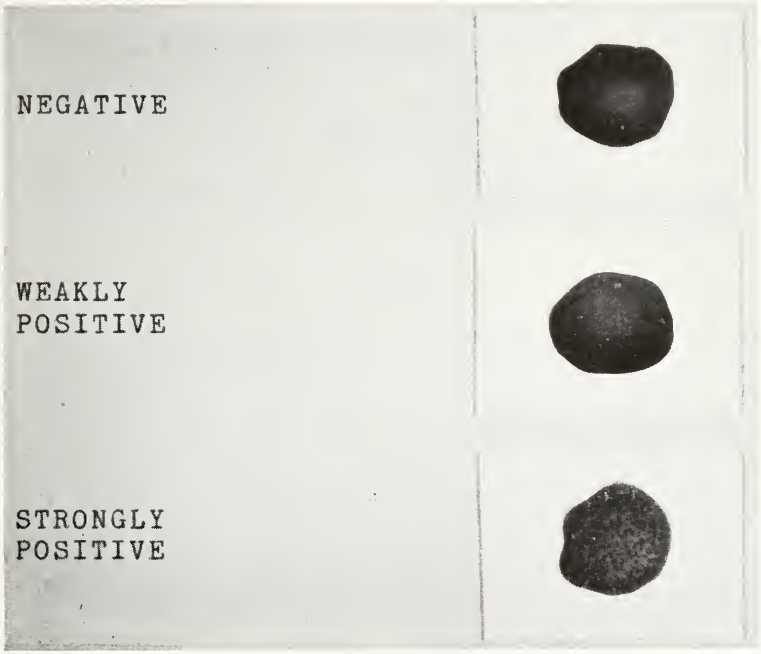

Fig. 1.

Results. Figure 1 shows the appearance of a negative reaction, a weakly positive reaction, and a strongly positive reaction, elicited by control bloods on hand in the laboratory. These control bloods had been bled at various times following the use of pertussis vaccine. The present group of 100 bloods was found to give almost uniformly the negative type of reaction as seen in figure 2. Only two of these gave what might be considered weakly positive reactions. This result may be the expectation in such a group of persons between the ages of 21 and 60, since most of these individuals would likely have had whooping cough 15 to 50 years previously, before widespread use of Phase I vaccine, and antibody incited at that time would have waned at the time of these tests.

Discussion. It is common knowledge that various serologic reactions, such as the Widal reaction, decline in strength in the years succeeding infection or use of vaccine. It appears that pertussis is no exception to this general rule, and although agglutinins and other antibodies may decrease in potency over a period of time even to the point of extinction

of any measurable reaction or titer, considerable specific resistance is known to occur. In all probability an incipient infection, long after antibodies have been produced and subsequently lost, can be dealt with adequately by means of an acquired adaptation to produce potent antibody in a very short period of time. In support of this idea in connection with

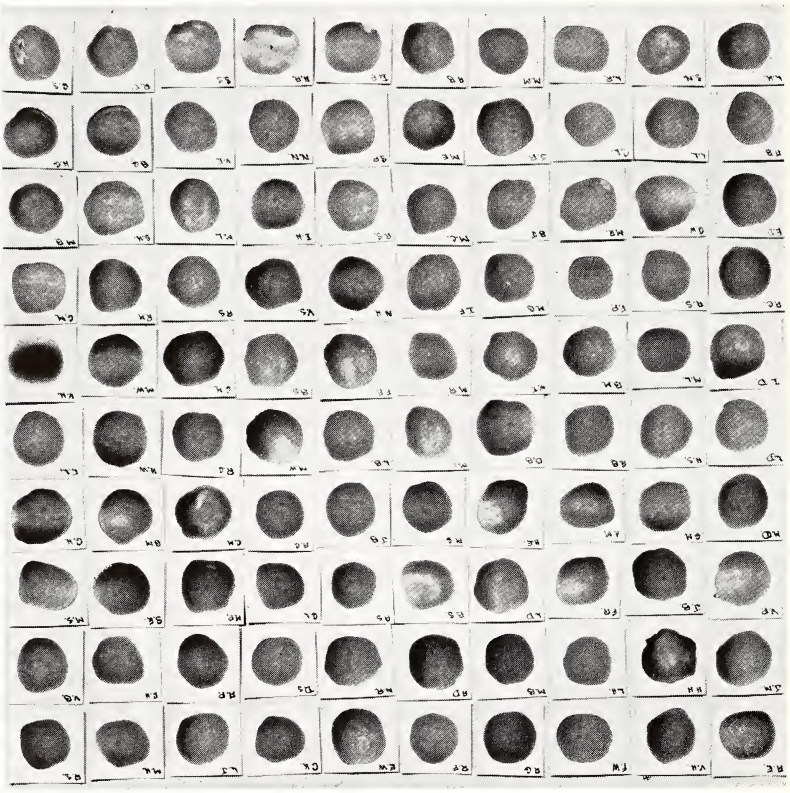

Fig. 2.

pertussis, we have observed that, within five years following pertussis vaccination, some 50 per cent of patients show no demonstrable antibody. However, these negative reactors produce strong agglutinin in a short period of two weeks following revaccination with a single small dose of antigen. (2) This accelerated rate of reappearance of substantial antibody appears sufficiently regular to comprise a rough serological indicator of previous specific vaccination in the absence of circulating antibody.

Conclusions. 1. Bloods from 100 healthy adult persons of both sexes covering a wide age group have been tested for presence of pertussis agglutinins by the rapid test.

2. With the exception of two weakly positive reactions, all of these gave essentially negative reactions.

3. There is no evidence from this group of tests that pertussis antigen is agglutinated non-specifically by normal human blood serum.

4. The above results verify a previous unreported series of tests we made eleven months ago on a sampling of 50 human sera from the same source as the bloods herewith reported. These former serum tests elicited practically all negative reactions, only one of these showing as weakly positive.

5. Absence of agglutinins for *H. pertussis* is not to be construed as evidence of susceptibility to pertussis, any more than absence of a demonstrable Widal reaction is to be construed as susceptibility to typhoid. It is obvious that previous host experience with the particular microorganisms should be taken into consideration.

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BOTANY

Chairman: RAY C. FRIESNER, Butler University

A. T. GUARD, Purdue University, was elected chairman of the section for 1943.

Kodachrome studies of trees in winter. C. L. PORTER, Purdue University.—A photographic study was made of a number of species of trees in their winter condition. Identifiable aspects of form and bark were presented. Some pathological conditions of trees were shown and discussed.

A new type of key for the identification of gilled mushrooms. C. L. PORTER, Purdue University.—Use is made of multiple-entry cards with perforated edges to key the distinguishing characters of gilled mushrooms. The plan is one adapted from a similar scheme used by the Forest Products Laboratory at Princes Risborough, England, for the identification of hard woods. A similar key could be used for the identification of other members of the plant kingdom.

Development of the seed of the tulip tree. A. T. GUARD, Purdue University.—Collections of the flowers were made at five day intervals from the early bud stage until August 1 in order to study the development of the seed. There was a vigorous development of the nucellus in the early stages. The embryo and endosperm did not begin to develop until about four weeks after the flower had opened.

An ecological survey of Berkey woods, a remnant of forest primeval in Kosciusko county, Indiana. J. E. POTZGER and RAY C. FRIESNER, Butler University.—The paper is an addition to the quantitative and qualitative studies of comparatively undisturbed forests in Indiana. The specific aim is to perpetuate a record of their true composition. The study is based on 50 100-square-meter quadrats. Considered are the sociological factors frequency, density and basal area. The Berkey woods is a typical mesophytic climax forest of Indiana in which *Acer saccharum* and *Fagus grandifolia* play the most prominent role. Associated with them, however, are 16 species of tall trees, stamping the stand as mixed mesophytic. Both Acer and Fagus reproduce well. Woody species are represented by 18 tall trees, 3 small trees, 9 shrubs and 1 liana. *Ostrya virginiana* is the most important representative in the small tree stratum, and *Asimina triloba* in the shrub layer.

Notes on the venation patterns of the stipules and calyces of some legumes. LAWRENCE J. KING, Earlham College.—The venation pattern of stipules and calyces was studied in thirteen species representing six genera. These patterns were found generally to be distinct and

characteristic of each species. The characteristic patterns of each species were described.

The effect of different sources of Nitrogen on Phosphorus deficiency in tomato plants. W. R. MULLISON, Purdue University.—It has been reported that the application of N in a reduced form such as urea enabled calcium-deficient plants to continue growth for a much longer period of time than similar plants supplied with an oxidized form of N such as nitrates. It was thought that supplying N in a reduced form might have a favorable effect on plants given little or no P by slowing down the onset of that deficiency. The experiment was performed first with plants that had been grown the first month in quartz sand and supplied with a complete nutrient solution. Later the experiment was repeated with plants which were P-deficient from the time of germination. The results showed that N supplied in the form of urea and ammonia does not delay the appearance of P deficiency symptoms as well as N supplied in the form of nitrates.

Studies on the nutrition of *Collybia velutipes* (Curt.) Quel. BROTHER RAPHAEL MARCZYNSKI, University of Notre Dame.—*Collybia velutipes* (Curt.) Quel., an agaricaceous fungus, was grown in pure culture on a synthetic medium with the addition of various supplements. Yeast extract, malt extract, bacto-peptone, bacto-agar, thiamin, thiazole, pyrimidine, and biotin increased growth. Riboflavin, pyridoxine, and glycine had no effect.

Observations on the vitamin requirements of *Stereum frustulosum* (Pers.) Fr. N. L. NOECKER and MERTON J. REED, University of Notre Dame.—*Stereum frustulosum* was investigated concerning its vitamin nutrition. The basal medium consisted of ammonium tartrate, M/10; sucrose, M/5; potassium phosphate, M/20; magnesium sulphate, M/100; ferric chloride, 0.6 cc. of a one percent soln.; and distilled water to make 1000 cc., and was used with and without the following supplements: thiamin, intermediates of thiamin, biotin, pyridoxine, riboflavin and yeast extract. Of the vitamins tested, thiamin was the only one which had a beneficial action, being able to replace completely yeast extract as a growth stimulant. This vitamin, added to the basal medium, produced an increase in growth of approximately 50% (growth on the basal medium alone, 13.1 ± 0.70 mg.; basal medium + thiamin, 18.4 ± 1.83 mg.). The optimal concentration of thiamin was 0.1 gamma per 25 cc. The thiazole portion of thiamin was as effective as the whole molecule. Apparently the pyrimidine component is synthesized in adequate amounts. An active factor of strictly physico-chemical nature was suggested by the results obtained by the addition of a small amount of purified agar to the basal medium containing yeast extract.

Some Aspects of Tree Growth

Ray C. Friesner, Butler University

Interest in the general subject of tree growth is by no means recent. According to Glock (11) the literature of the nineteenth century contains many references bearing in one way or another upon the matter of growth in trees. Apparently the earliest, as well as the most sustained interest, has been displayed with regard to the nature and significance of growth rings. But in spite of this long period of interest and its consequent stimulus to study, there still remain today a number of important unsolved problems—such problems, for example, as: (1) the relation of growth to total rainfall; (2) the rainfall period showing highest degree of correlation with growth; (3) relation to temperature; (4) relation of vertical growth to diametral growth; (5) relation of vertical growth to environmental factors; (6) correspondence of elongation both as to initiation and duration in different parts of the same tree.

In the development of my subject I should like to treat it under three main subdivisions, viz. (1) Elongation; (2) Diametral growth during the current season; (3) Annual ring studies of past years.

Elongation

Time of Initiation. The time of awakening of bud activity is a direct response of the individual to factors of the environment, the most important of which, insofar as any particular species, in successive years, is concerned, is temperature. Each species shows its own specific relation to temperature. Apparently, pines initiate vegetative bud-activity about one to three weeks earlier than some of our hardwoods. In 1941 (8) *Pinus resinosa*, *P. sylvestris* and *P. banksiana* began activity in Brown County, Indiana, during the week ending April 13, and *P. strobus* during the following week while during the same year, in Marion County, activity began in *Fagus grandifolia* and *Quercus alba* during the week ending April 21, in *Ulmus americana* and *U. fulva*, April 28 and in *Fraxinus americana*, May 5. Other broad-leaf trees, however, are as early in growth initiation as the pines, e.g. *Acer saccharum* in 1941 began during the same week as the pines.

In 1942 *Fagus grandifolia* and *Quercus alba* showed initiation of bud activity during the week ending April 20, *Fraxinus americana* during the week ending May 4, while *Pinus strobus* began April 15 and *P. resinosa*, April 6.

In more northern latitudes initiation comes later but the relationship in times of initiation between conifers and broadleaf species remains about the same. Thus, in *Pinus resinosa* elongation began at Ithaca, N. Y., May 7 (1), at Stephentown, N. Y., April 27 to May 12 (3), at Keene, N. H., May 15 (13), and in northwestern Connecticut (14) the 4-year average in 23 individuals was April 27. The broadleaf species, *Fraxinus*

americana, *Quercus rubra* (probably *Q. borealis* var. *maxima*), *Acer rubrum*, *Betula populifolia* and *B. papyrifera* all began at about the same time as that for *P. resinosa*.

Behavior and Duration of the Growth Curve. The elongation growth curve for every species of tree studied exhibits essentially a grand-period type of behavior wherein activity begins slowly, accelerates with increasing rate to a maximum and decelerates in much the same, except inverse order to a dragging minimum followed by complete cessation. Published data of this type includes *Pinus strobus* (8) (3) (24), *P. resinosa* (8) (1) (3) (13) (14) (26), *P. sylvestris* (8), *P. banksiana* (8), *Larix laricina* (3), *L. decidua* (3) (14), *Picea abies* (3), *P. canadensis* (3), *P. rubra* (3), *Tsuga canadensis* (3), *Fraxinus americana* (14), *Quercus borealis* var. *maxima* (14), *Acer rubrum* (14), *Betula papyrifera* (14), and *B. Populifolia* (14). Various modifications of the symmetrical grand-period curve are found, e.g. either the accelerating or the decelerating side may be much longer drawn-out than the other side; either side may have flat or nearly flat places; double peaks may occur and they may be either essentially equal or they may be quite unequal with the secondary peak coming on either the accelerating or the decelerating side.

Apparently the essential character of these curves is little modified by external conditions. The time when elongation begins, the height of its peak, and the total amount of elongation are affected to some extent by external factors of both the present season and the past season. The height of the curve and total elongation are especially influenced by both available reserves constructed and stored during the past season and by available moisture during the present season.

Modifications of the symmetrical grand-period curve are probably largely due to internal factors such as availability and activity of enzymes and growth hormones, and conduction problems of water, minerals, and food reserves.

The duration of the growth curve varies with different species and also with different individuals of the same species. In *Pinus strobus* the total range for all individuals is 49-84 days with 81% of the individuals showing 56-70 days, (8). In *P. resinosa* the total range is 45-70 days. In Brown County, Indiana, (8) 76% of the individuals showed 63 days; at Keene, N. H., and in northwestern Connecticut Kienholz (13, 14) found the average to be 60 days; at Ithaca, N. Y., Baldwin (1) found it to be 69 days, while at Stephentown, N. Y., Cook (3) found it to vary over a five-year period from 45-63 days. In *P. sylvestris* the range (8) is 56-84 days with 78% of the individuals showing 56-63 days. In *P. banksiana* (8) the range is 49-84 days with 90% of the individuals showing 56-70 days. Apparently, there is no correlation between time of initiation and length of duration, nor is there any correlation with initial height of the individual.

Kienholz (14) found that broadleaf species fall into 2 groups on the basis of height growth behavior. In the first group height growth rises rapidly to a climax in late May (in Connecticut) and falls off to zero by late June with a total growth period of about 60 days. Of this growth 90% occurred in the 30 days beginning within 1 or 2 weeks after initiation

of activity. Species belonging to this group are *Quercus borealis* var. *maxima*, *Acer saccharum*, *A. rubrum*, *Fraxinus americana*, and *Fagus grandifolia*.

In the second group growth begins about the same time but rises more gradually to a climax which was reached in Connecticut in mid-June and then falls off to zero by mid-August with a total growth period of 110 days. In this group 90% of the growth occurred in the 60 days beginning 3-4 weeks after initiation of activity. *Betula populifolia*, *B. papyrifera* and probably *Liriodendron tulipifera*, *Populus grandidentata* and *P. tremuloides* belong to this second group.

There is a remarkable similarity in the behavior of the growth curve in the same species in successive years. Tryon and Finn (26) found that the peak of growth came in *Pinus resinosa* and *Picea glauca* at the same time for each of 3 years and in *Larix decidua* it came at nearly the same time for each of these years. Stevens (24) and Kienholz (13) found similar results in *Pinus resinosa* and *P. strobus* and Kienholz (14) found nearly similar results for *Fraxinus americana*, *Quercus borealis* var. *maxima*, and *Acer rubrum* over a 4-year period. Species with longer growing period showed greater variation in this regard.

In every individual the midsummer zero-point is followed by some further elongation, varying from zero to a few mm per week. In a few individuals (approximately 10%) this post-midsummer elongation is true stem elongation but in the greater majority (approximately 80%) of the individuals, it is probably confined to elongation incident to bud formation because the total amount of elongation does not exceed the original length of the winter buds. Of the individuals showing true post-midsummer stem elongation, 80% were *Pinus banksiana*.

In young trees the total amount of seasonal elongation of the primary axis shows a relation to the initial height of the trees. Taller size-classes show greater average elongation than shorter size-classes. This would undoubtedly find a limit in height-class beyond which it would not hold, but no data are at present available on this point.

When elongation of different axes of the same tree is considered it is found that the primary axis initiates growth earlier, continues longer and attains greater total elongation than axes of secondary or lesser rank. Secondary axes average greater elongation than tertiary and those nearer the top of the tree begin earlier and attain greater total growth than those farther from the top.

Diametral Enlargement

Initiation of growth. Diametral increase in trunks of most deciduous trees depends for its initiation upon the beginning of bud activity in the spring but this is not true of evergreen species, at least not in coniferous evergreens. The time of initiation of cambial growth in coniferous evergreens is more closely dependent upon temperature than any other factor of the usual environment. MacDougal (20, 21) has shown this to be true in *Pinus radiata* in California and my own unpublished data obtained by Mr. Gershom Walden show it to be true in *Pinus strobus* in Maine.

In most deciduous trees initiation of cambial activity occurs with or follows at some little time after the initiation of bud activity. A striking exception to this is found in Fraxinus. Chalk (2) working with *F. excelsior* and *F. oxycarpa* and MacDougal (21) working with *F. velutina* have shown that diametral enlargement begins as much as three weeks before vegetative buds begin to show activity. My own unpublished data show that it begins in *F. americana* at least a full week ahead of vegetative bud activity. In *Fagus grandifolia* (6, 9), *Acer saccharum* (21, 9) and *A. macrophyllum* (21) initiation of cambial activity ranges from just prior to shortly after the leaves have attained full size. In *Ulmus americana* (9, 16) and *U. fulva* (9), initiation ranges from just before to shortly after the beginning of vegetative bud activity but does not reach any considerable amount until leaves are nearly full size. In *Quercus velutina* (21), *Q. borealis* var. *maxima* (21) and *Q. alba* (9) initiation essentially coincides with beginning of vegetative bud activity.

Behavior of Growth Curve and Its Duration. Above we have shown that, in deciduous trees, the initiation of the growth curve is definitely related to time of awakening of bud activity. This, in turn, of course, is related to both external and internal environmental conditions, the most obvious and readily measurable of which, is temperature. The behavior of the growth curve, once it has started, is quite variable in different species and shows varying degrees of relation to measurable environmental conditions. In *Fagus grandifolia* (6, 9), the curve appears always to show a grand-period type of behavior. Environmental conditions, especially the temperature-available moisture-transpiration complex, play a prominent part in the time of initiation, the amplitude of the curve, and the time of its cessation, but not in the type of curve. That is to say, environment controls the quantitative but not the qualitative aspects of the behavior.

In other species, *Ulmus americana*, for example, the curve of growth rate has practically no resemblance to a grand-period type of curve. Successive weeks show almost continuous alternation of greater and lesser diametral increments (9) with no very definite relation either to amount of rainfall, average daily temperature or evaporating power of the atmosphere. In still other species, *Ulmus fulva*, *Acer saccharum* and *Quercus alba*, for example, the growth curve, while not illustrating the clean-cut grand-period type found in Fagus, approximates this type.

It must be remembered that diametral changes are a combination of the addition of wood and bark cells on the one hand and turgidity changes on the other. This is clearly shown by the fact that net diametral losses are encountered when available water falls below transpiration demands and by the presence of daily reversible variations to be discussed below. How much of the autumnal changes are true growth additions and how much are mere turgidity changes cannot be differentiated precisely, but it is certain that they are mostly turgidity changes, especially when the autumn is mild and dry, because the final diameter measurements in late December are never (in deciduous species) much more, and more often considerably less, than at the late summer zero-point.

Daily Reversible Variations. Hourly variations in diameter are recorded by the dendrograph during some parts of the vegetative season for all species studied. These daily reversible variations are entirely due to turgidity changes and set in whenever the transpiration loss exceeds the ability of the absorbing and conducting organs to supply water. The amplitude of these reversible changes is directly proportional to this net difference and amounts in concrete measurements to as much as 0.3 mm. The fact that these daily losses and recoveries continue for some little time after all leaves are either dead or fallen indicates that even twigs and buds, especially in mild rainless periods, may lose water during the light period of the day faster than it can be absorbed and conveyed past the point of diametral measurement.

MacDougal (21) has shown that there is a very close relation between the diameter of trees and available moisture in his irrigation experiments. Irrigation of a specimen of *Quercus agrifolia* (an evergreen oak) which had shown no growth increase for 3 weeks resulted in diametral increase within 2 hours after application of water.

For more detailed and thorough treatment of diametral growth changes the student is referred to MacDougal's "Tree Growth" (21).

Annual Ring Studies

In the preceding 2 subdivisions of this discussion attention was focussed upon current-season growth. In this final subdivision I should like to summarize some of the more important data dealing with growth during past years as revealed in a study of growth rings. For an exhaustive resume of the relation of such data to climate the student is referred to Glock's (11) able treatment in Botanical Reviews. If one is interested in a still broader consideration of the entire field of growth rings there is available a bibliography by Schulman (23) published in "Tree-Ring Bulletin" in April, 1940. The former of these articles contains a bibliography of 203 references and the latter, 412.

Relation to Rainfall. The problem of sorting out the different factors of the environment and determining just what role each plays in the matter of growth is well nigh unsolvable because the behavior of the individual is its response to its total environment.

Nevertheless, some of the factors of the environment are much more nearly uniform for any particular individual from year to year than others and hence wide variations in growth from year to year may reasonably be concluded to be due to those factors of the environment which also have a wide variation during the same time interval (15). Thus, of all the factors of the external environment, rainfall, amount of sunlight and temperature are probably the most variable from year to year. These three factors have a definite inter-relationship to each other. Any one of them may become a limiting factor.

Rainfall becomes more important during periods when available moisture is near the critical point. It has been shown (7) that there is a much closer correspondence between width of year-rings and rainfall when there is a considerable decrease following a year of average

rainfall than when the same amount of decrease follows a year when rainfall was well above the average. The converse is also true, viz. a considerable increase in rainfall in one year is accompanied by greater increase in growth when it follows a year deficient in available moisture than when it follows a year of nearly average rainfall. Thus it is apparent that tree growth reflects rainfall only when the latter is such as to influence the physiological processes of the tree. It must, therefore, be obvious that rainfall during some rainfall periods will be far more critical than that during others. These rainfall periods which are most critical will vary with different species of trees, with different types of topography and to a less extent in the same species and on the same site with different years depending upon rainfall in other rainfall periods.

In New England, Lyon (19, 17) finds no consistent correlation between any rainfall period and growth rings in *Pinus nigra* var. *austriaca*, *Picea excelsa* and *Larix decidua* while there was significant correlation in the case of *Pinus strobus*, *Pinus sylvestris*, *Tsuga canadensis* and *Quercus borealis* with rainfall during April-August and a number of combinations of months between these. In an earlier study Goldthwait and Lyon (12) found *Pinus strobus* (also in New England) to show closest correlation between year-ring width and rainfall during the months of May-July.

In northern Indiana Diller (4) found growth in *Fagus grandifolia* to show closest correlation with rainfall during the month of June while in the Knobs area of southern Indiana, Kleine, Potzger and Friesner (15) found annual-ring width in *Quercus alba*, *Q. borealis* var. *maxima*, *Q. montana* and *Q. velutina* to correlate with rainfall for June-August in 19 out of 24 years, with April-May in 4 of the remaining 5 years and with annual rainfall in the other year.

Rainfall for the calendar year as a whole has been found to show significant correlation in some studies, e.g. in the case of oak in Illinois (10), *Juniperus virginiana* in Nebraska (27). Rainfall periods consisting of many other combinations of months have been found significant for different species and in different areas, e.g. the vegetative year, i.e. November to and including the following October; the water year, i.e. October to the following September; September-August; August-July; 15-month period, June of one year to and including August of the following year; January-August; January-July; January-May; March-June; March-May; April-May.

The differences in rainfall periods correlating best in different areas and in different species are partly explainable on such bases as differences in time of most active growth in different species; differences in topography; differences in time of growth season in different geographical areas and differences in rainfall of past periods.

The correlation in *Fagus grandifolia* for the month of June is significant in view of the fact that dendrometer studies have shown (6, 9) that 70% of the annual diametral increase in this species occurs during this month and an additional 10% during the following month. The correlation in Quercus with rainfall for the June-August period is significant

from two standpoints. Dendrometer studies (9) show that 62.5% of the diametral enlargement occurs during this same period and the studies were made in a region with such high relief that run-off is always high, this offering little opportunity for much moisture carry-over from previous periods. The fact that 4 of the 5 years showing no correlation with June-August rainfall showed correlation with April-May rainfall is also significant in view of the fact that the remaining 37.5% of growth occurs during April and May.

The fact that the same species may show best correlation with different rainfall periods in different geographical areas and under different topographical conditions is well illustrated by the differences shown by oaks in different areas. In the Knobs of Indiana where relief is high the most significant correlation (15) was with rainfall for June-August. In Marshall County, Indiana (7), on a site where relief is very little, the most significant correlation in *Quercus alba* was with rainfall for the 12-month period November-October, but in *Q. borealis* var. *maxima* it was with rainfall for June-August. In Illinois, Fuller (10) found the calendar year most significant while in Missouri, Robbins (22) found rainfall for March-June most significant and in New York, Stewart (25) found June-July to correlate best.

The same rainfall-period does not always necessarily have equal significance in any two successive years, especially when topographic conditions are such that there is opportunity for sufficient water to soak in and be held as a carry-over from a previous rainfall-period. This is well illustrated when we consider the June-August rainfall-period for Indianapolis for the years 1940 and 1941 (9). In 1941 the June-August rainfall was 93.86% of normal while in 1940 it was only 55.4% of normal. However, diametral increase in *Fagus grandifolia* (6, 9) was 17.9% greater in 1940 when June-August rainfall was 55.4% of normal than in 1941 when rainfall was 93.86% of normal. This is correlated with the fact that the lower rainfall in June-August 1940 followed a January-May rainfall which was 87.73% of normal while the higher rainfall in June-August 1941 followed a January-May rainfall which was only 37.9% of normal.

Relation to Temperature. Temperature probably plays its most significant role in determining the time of initiation of growth but shows only an obscure and indirect relation to the quantity of growth. Of course, it must be remembered that the response of the organism is to the sum total of its environmental conditions and that temperature is a part of this total. On the other hand, other factors which enter into this total, more particularly available water, are more likely to constitute the "bottle-neck" in the factor complex. If all factors exclusive of temperature were at their optimum, then a definite relation between growth and temperature would be readily demonstrated, but in nature this probably seldom occurs except at the beginning and end of the vegetative season or in higher latitudes.

Significantly enough the relation between temperature and growth, to the degree to which it can be established, is mostly inverse in lower latitudes and direct in higher latitudes.

In Finland and northern Sweden, Erlandsson (5) found a direct relationship between July temperature and growth but the curves show agreement in only about ⅔ of the years. In New England Goldthwait and Lyon (12) found the relation between growth in *Pinus strobus* and temperature to be direct for April-May and inverse for June, while Lyon (18) found in *Tsuga canadensis* a positive relation to March-April temperature but no consistent relation to that occurring during the growing season.

In almost all cases in warmer latitudes, summer relationships, if detectable at all, have been of an inverse character but that relationship has often been weak and the two curves may parallel or oppose each other in different years. Diller (4) found that the relationship is inverse for *Fagus grandifolia* with June temperature for northern Indiana in 19 out of 20 years. Kleine, Potzger and Friesner (15) found best correlation for four species of Quercus to be inverse with June-August temperature but there were numerous exceptions.

The fact that the effects of temperature upon tree growth are both direct and indirect is understandable when we recall that while increase in temperature up to its optimum will speed up the physiological processes concerned in growth it will also result in greater demands upon the water supply to replace that lost through increasing transpiration rate. When water is abundant an increase in loss through transpiration may even help growth through aiding in transport of mineral salts but on most sites water supply is more apt to be a limiting factor during the growing season and hence increased temperature resulting in increased transpiration causes a reduction in growth rate.

The fact that the inverse relationship is for different periods in different species of trees is, in part, at least, correlated with differences in times when the larger percentage of growth occurs. Thus, the inverse relation between growth in *Fagus grandifolia* and June temperature (Diller, 4) is correlated with the fact that 70% of the growth in this species occurs in that month (14, 15); while the inverse correlation between growth in Quercus and temperature during June-August is correlated with the fact (15) that 62.5% of the growth occurs during this period.

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Color Inheritance in Hybrid Freesias

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The history of the commercial introduction of "Freesia refracta alba" and its hybrids was presented in previous papers. Although the popularity of the plant has declined in recent years, thousands of corms are produced each year in California and sold to northern florists for the production of cut flowers during January, February and March. The results presented here have been gathered over a period of years beginning in 1927 in a project mainly concerned with the commercial production of new varieties of Freesias. The hybridizing, selection, trial and early development of clones has been carried out in the greenhouses of Elder Brothers, Inc., at Indianapolis. More than 300 planned crosses have been made in a single season which has yielded more than 30,000 seedlings. Seedlings produce typical blossoms in their second season after which all but a few plants are destroyed. Corms of the new "varieties" are produced commercially in the vicinity of Oceanside, California where climatic conditions are favorable for the successful growth of Freesias and other plants of South African origin.

Early in this work it was recognized that many phases of the project would be clarified if specimens of the original species could be obtained. Through the help of Professor Robert Compton, Director of the Botanic Gardens at Kirstenbosch, Cape Province, and several South African amateur botanists, live specimens were imported. These included several species that were new to botanists. Corms of the "pink" species *F. Armstrongi* were collected from the same clump as that which supplied the type specimen (Fig. 2). Importance is attached to this item because most records of the development of colored freesia hybrids date from 1905 when corms of this species arrived at Kew Gardens in England. *Freesia Andersoniae* (Fig. 7), and *Hurlingii* (Fig. 3), were also used in this study. These two species have been described in recent years and were not available during the time that the hybridizers were developing the forms that have been introduced commercially. In addition to known species, collected specimens from remote localities differing from anything yet described were also supplied. Identification of these new forms was never made due to the untimely death of Dr. N. E. Brown whose revision of the Genus Freesia appeared in 1935.

All of the species may be crossed with many of the hybrids and all species would cross with one or more of the species. All species blossomed in the greenhouse during the months of January, February, and March which permitted crossing the last blossoms of the early species with the first blossoms of the latest species. In addition to supplying material for the study of the inheritance, these species have contributed many

new characters to the genetic complex associated with hybrid freesias. This includes genes for the production of at least two new types of fragrance, new blooming dates, new flower forms, new leaf and spike

Plate I. Fig. 1, Commercial Variety, "Giant White." Fig. 2, Freesia *Armstrongi*. Fig. 3, Freesia *Hurlingii*. Fig. 4, white hybrid with yellow spots on three lower segments. Fig. 5, bright yellow hybrid with deep crimson spots. Fig. 6, hybrid showing lines, venation and spotting.

arrangement, new corm shape, etc., etc. Whether these features will have commercial value is a question that cannot be answered under present conditions.

Hybrid freesias exist in pure white and colors ranging from ivory and light yellow to orange, pale pink to deep, dull red and bright crimson, brown and bronze, pale lilac to deep bluish violet, with and without colored lines and with varying amounts of yellow on the three lower segments. Descriptions are based primarily on the color of the inner part of the corolla. With few exceptions dingy white with yellow splotches and various shades of yellow were the only colorings listed until the addition of the species *Armstrongi* resulted in hybrids far different from its pinkish hue. The color of this species has been given as "pinkish-mauve," "bright rosy pink," or "pink." However, flowers produced in the greenhouse were "phlox pink to pale amaranth pink, striped phlox purple" according to Ridgway color chart. No other pink species has been described. With flowers of *Armstrongi* available, analysis of its contribution was made by numerous crosses with plants that had been progeny tested or were of known parentage.

The results of crosses with *Armstrongi*, especially during 1933 and in subsequent seasons, served as a basis for interpreting the results of crosses among lavender and pink hybrids which had been gathered in previous years. F_1 from crosses with the variety Giant White were

Fig. 7, Freesia *Andersoniae*.

These results confirmed the findings from crosses among the hybrids in which the bluish lavenders were recessive to the pinks. From the results of Scott-Moncrieff, Smith, Onslow, and others on the chemistry of the anthocyanin color was gained from crossing *Armstrongi* with the species *Hurlingii* whose upper segments are dingy green overlaid with "dull bluish purple." F_1 from this cross were all bright pink (Fig. 8). all pale pink with red stripes. Crosses with seedling No. 519, a medium bluish-lavender, produced progeny that were all light pink with darker stripes. Further evidence of the dominance of the pink (reddish) phase

of flower pigments, and simple tests on freesia flowers as a part of this study, it was concluded that this condition was controlled by a single pair of genes. The dominant gene *M* produced a lowering of the pH of the cell sap giving shades of red while the recessive *m* raised the pH changing the anthocyanin to blue.

Since the species crosses produced few seeds for tabulating F_2 results, the interpretation of the genes controlling anthocyanin formation was based on crosses among white and colored hybrids where larger numbers could be easily produced. For this Giant White (Fig. 1) and the white seedlings No. 105, No. 102, No. 117, No. 832, and the varieties Purity and imported *Refracta* alba (F.*lactea*?) were used. Although more crosses were made with lavenders and blues than the pinks and reds the distribution of color intensities were the same. The results could be classed as white, light, medium, deep and dark. This was interpreted as being due to two pairs of cumulative genes, *A* and A_1 which controlled the production of anthocyanin. Various crosses indicated the production of this pigment was independent of the yellow pigments and the effects of genes *A* and A_1 were limited to certain areas of the corolla. The "blotches" on the three lower segments, usually yellow, were found to be produced by separate genes (Fig. 4). To some extent the flower size, or more specifically, cell size, is correlated with color intensities, the small flowers being darker than the larger of same gene combination. Plants having defective roots or stems produced darker, smaller blossoms that had to be carefully checked in the tabulations.

A dominant gene *L* produced lines in the center of the flower segments in the presence of pigment. The data on this is incomplete and other genes are certainly involved since each of the six segments may have as many as three lines, only one, or more often, none on the upper segments.

Fig. 8, All-pink hybrid from F. *Armstrongi* x F. *Hurlingii*.
Fig. 9, White hybrid with deep "purple" spots.

In the use of the white species *Andersoniae* in crosses with red and blue freesias some unexpected results were obtained. Crossed with medium blues and reds the results were white in the fully expanded blossoms instead of being light blue or light pink. When crossed with dark blues and reds the results were light blues and pinks but not the expected medium blues and reds. A reduced number of the expected intense colors were regained in F_2 indicating the presence of the normal number of *A* genes. This was interpreted as being due to the incompletely dominant gene, *I*, whose effect was limited to the areas covered by *A* and A_1 but not on *L*. Figure 10 shows three blossoms of *Andersoniae*. The last two are aging and are becoming mottled with deep purple, however this is not the pathological mottling as seen in "broken" tulips. Apparently the *I* genes lose their effect as the blossom ages.

Both the effects of gene *I* on the anthocyanin colors and the effects of two more genes controlling the production red or blue "splotches" on the three lower petals is shown in the progeny of *Andersoniae* crossed with seedling No. 856. Blossoms of this plant are deep pinkish-red with deep red spots on the three lower "petals." The F_1 of this cross had white in areas controlled by *A* and A_1 but with red or blue splotches on the three lower segments, a new color arrangement for hybrid freesias. This is shown in Figure 9. This was due to No. 856 having the genetic formula of $AAA_1a_1 Mm$ with the cumulative "pansy" genes *P* and P_1. This was verified by further crosses. Figure 5 shows these "pansy" spots of deep crimson in a flower that is otherwise a deep yellow. The area covered by the last genes is identical with that covered by cumulative genes *S* and S_1 controlling the formation of yellow "blotches" (Fig. 4). These are independent of the *P* genes and varying amount of yellow pigment with either blue or red may be found in the same flower.

Yellow plastid pigment is found in most of the freesia hybrids either alone or in combination with anthocyanin. These crosses of yellow hybrids, especially with the white hybrids listed above, gave color intensities at first somewhat confusing due to the fact that the presence of a single *Y* gene produced ivory which would usually be classed as "white." The presence of the usual yellow spots on the three lower segments of true whites contributed to the confusion. By separating

Fig. 10, Flowers of F. *Andersoniae* showing purple mottling that develops as blossoms age.

these two groups it became easy to separate the gradations thus: white, ivory, light yellow or lemon, deep yellow and orange yellow. This being interpreted as being due to two pairs of cumulative genes Y and Y_1. One hybrid, Giant White, was especially valuable in the crosses used to make the above color analysis (Fig. 1). This variety (clone) lacks any of the dominant genes mentioned above. Since the genes for general flower color are independent, many color variations result from the A and Y genes in the presence of M or m. For instance: with M the range may extend to crimson when homozygous for both A and A_1 and heterzygous for Y. When the combinations are reversed with more Y than A genes, orange color results. However, an orange yellow results in the absence of A but homozygous for both yellow genes (Y and Y_1). In the presence of the gene m, increasing the pH, various shades of bronze to brown result.

The above summary of data has not included the inheritance of color in stamens or their filaments, throat markings (which are conspicuously different in *Andersoniae*), external parts of the corolla, colored venation, "picotee" distribution, length and reduction in number of colored lines (structurally three mid-lines are present in each segment, regardless of color (Fig. 6)). Although the above genes account for all basic coloration in intensities, shades, and distributions, it is recognized that there must be genes that modify the expected results. These exceptions appear mainly as extremes, intermediates, or modification of color boundaries. In part may be due to genes modifying the formation of these complex flower pigments or their precursors. Chromosomal irregularity has been demonstrated in these hybrids and this may account for some of the exceptions.

The above interpretations seem to answer the question concerning origin of certain of the genes which gave rise to so many color combinations. Apparently the m gene was present in early white and yellow hybrids. That one pair of A genes was present is certain since one pale lavender variety was shown before the species *Armstrongi* made its appearance. Since *Armstrongi* is homozygous for a single pair of A genes, it is assumed that the second pair of A genes present in the hybrids had a different origin. It is quite possible that the first source of anthocyanin came from the species here referred to as *Hurlingii*. Specimens of this species were collected at Bonnievale, Cape Province, and are identical with those figured by Jacquin in 1786 and named *Gladiolus refractus* while the same species was figured in the Botanical Register of 1816 and named *Tritonia refracta*. The same species became Foster's *Freesia refracta* in the Gardeners' Chronicle of 1888 and *Freesia Hurlingii* as figured by L. Bolus in South African Gardening in 1933. The fact that the name *refracta* has been used to refer to freesias in general resulted in the name *Hurlingii* being chosen as the most useful in the designation of the plant used in this study. Since this inconspicuous species with flowers "dingy greenish, suffused violaceous or purple" loses its color identity in F_1, it is quite certain the early hybridizers would avoid retaining any reappearance of its general flower characteristics. In spite of this it may have been the source of the one pair of A

genes and it certainly is homozygous for *m* although the *I* gene referred to above is also present. These facts are not readily seen in F_1 progeny but F_2 produced flowers with anthocyanin intensities which would be difficult to explain otherwise. The source of the yellow colors in the hybrids would be difficult to explain since the early hybridizers probably had access to corms of more than one yellow flowered species.

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Studies in Indiana Bryophytes V

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The mosses used in this study are Indiana collections in herbaria in the following institutions: Indiana U., Butler U., DePauw U., U. of Illinois, Earlham College, Field Museum of Natural History, and the New York Botanical Garden.

The nomenclature is that of A. J. Grout, The Moss Flora of North America North of Mexico 2:67-89 and 145-180 (1935).

The asterisk preceding the name of a county indicates that the species has been collected in that locality according to published records but has not been studied by the author. The asterisk following the name of a species is an indication that, according to available literature, this is the first published record for Indiana.

The distribution range of each species has been extended by the author's collections which were made by the financial assistance of an Indiana Academy of Science research grant through the American Association for the Advancement of Science and by the aid of a research grant from the Graduate Council of DePauw University.

EPHEMERACEAE

Plants minutes, up to 2 mm. high, almost stemless, growing on moist, bare soil; protonema persistent and much branched; plants consist mainly of bud-like clusters of leaves and subglobose nearly sessile capsules; peristome none; spores large, globular to kidney-shaped, roughened; calyptra small and usually persistent.

1. Leaf margins slightly serrulate; capsule with rudimentary operculum ..... *Nanomitrium*
   Leaf margins spinose-serrate above; capsule without operculum, opening irregularly ..... *Ephemerum*

Ephemerum

E. serratum (Hedw.) Hampe.* (Figs. 1-2.) Leaves lanceolate, ecostate, upper margins spinose-serrate, up to 1.4 mm. long; calyptra reaching middle of capsule; capsules glossy, reddish-brown, subglobose, short-apiculate, without operculum, cleistocarpous, with stomata; spores 50-70μ in diameter, warty, maturing from winter to spring. Putnam County.

E. crassinervium Hampe, collected by J. P. Naylor in Putnam County, was reported by T. G. Yuncker in Proc. Ind. Acad. Sci. **30**:234. 1920. I determine the plants to be *E. serratum.*

Nanomitrium

N. Austinii (Sull.) Lindb.* (Figs. 3-4.) Leaves ligulate-lanceolate, ecostate, slightly serrulate, up to 1 mm. long; calyptra minute; capsules

without stomata, operculum rudimentary; spores 24-30μ in diameter, finely roughened, maturing from late autumn to early spring. Putnam County.

FUNARIACEAE

Plants usually annual, growing on soil which is bare or only sparsely covered with other plants; upper leaves commonly closely clustered and erect to erect-spreading; costa strong; leaf cells parenchymatous.

1. Capsules immersed ..... *Aphanorhegma*
   Capsules not immersed 2
2. Capsules strongly unsymmetric and curved; peristome double ....
   ..... (Cord Moss) *Funaria* .. 3
   Capsules symmetric, erect and urn-shaped; peristome lacking ....
   ..... (Urn Moss) *Physcomitrium*
3. Leaves long acuminate; costa frequently excurrent; spores 20-25μ in diameter, finely roughened when mature ..... *Funaria flavicans*
   Leaves short acuminate; costa usually percurrent; spores 14-17μ in diameter, very smooth when mature ..... *Funaria hygrometrica*

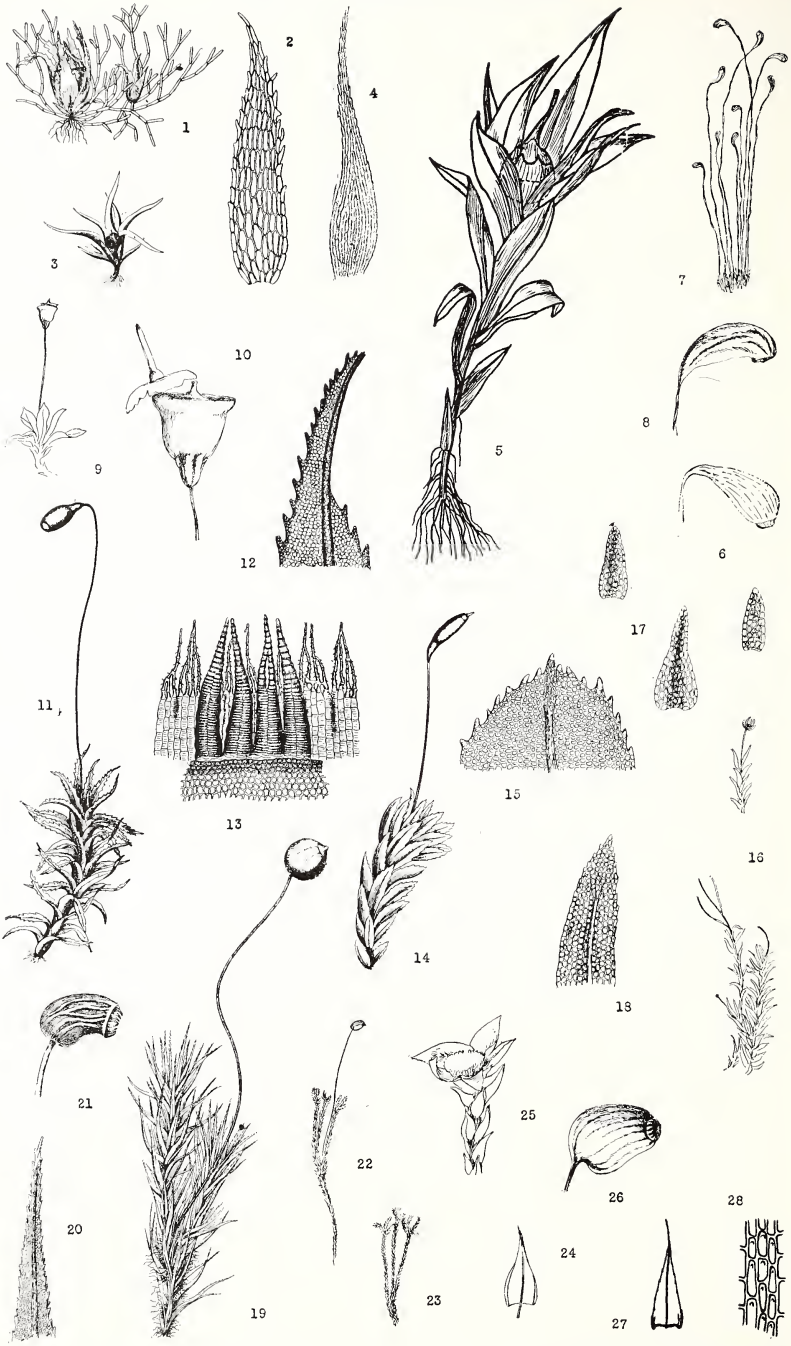
Aphanorhegma

A. serratum (Hook. & Wils.) Sull. (Fig. 5.) Plants up to 5 mm. high, growing on damp, clayey soil; upper leaves oblong-lanceolate to oblong-obovate, acute to acuminate, upper margins serrulate; costa ending in or just below the apex; capsule immersed, spherical, light brown when ripe, opening equatorially along a clearly marked line of dehiscence, wall cells distinctly collenchymatous; operculum half spherical, obtusely apiculate; calyptra campanulate-mitrate, 4-6 lobed, covering upper half of operculum; spores 22-30μ in diameter, papillose-spinose, mature in autumn. Monroe and Putnam Counties.

Funaria

F. flavicans Mx. (Fig. 6.) Plants similar in appearance to *F. hygrometrica*; upper leaves slenderly acuminate by excurrent costa; capsule globose-pyriform, urn is much less furrowed, mouth less oblique, and capsules shorter and less unsymmetric than in *F. hygrometrica*; spores 20-25μ in diameter, finely roughened, mature from spring to summer. Clark, Jefferson, Lake, Monroe, and Putnam Counties.

F. hygrometrica Hedw. (Figs. 7-8.) Plants loosely gregarious, light green, 3-10 mm. high; young upper leaves closely imbricated into a bulb-like tuft; costa stout, ending just below apex to very shortly excurrent; calyptra inflated-cucullate, rostrate; capsule subpyriform, urn very unsymmetric and arcuate, deeply sulcate when dry, mouth so oblique that it is often nearly parallel with the axis of the urn; spores 14-17μ in diameter, very smooth, mature from spring to summer. Carroll, Cass, Clark, Crawford, Dearborn, Delaware, Dubois, Elkhart, *Hamilton, Huntington, Jasper, Jefferson, Kosciusko, Lagrange, Lake, Lawrence, Madison, Marshall, Monroe, Montgomery, Newton, Noble, Parke, Porter, Putnam, Shelby, Steuben, Wayne, Wells, White, and Whitley Counties.



All figures (with the exception of 5, 27, and 28) are taken with permission from A. J. Grout, Mosses with Hand-lens and Microscope (M.H.M.). Fig. 5 is drawn from Sullivant, Icones Muscorum (Icon. Musc.), pl. 57. Figs. 27 and 28

Physcomitrium

P. turbinatum (Mx.) Brid. (Figs. 9-10.) Plants gregarious, up to 12 mm. high; leaves 3-5 mm. long, oblong-oblanceolate or obovate-lanceolate, acuminate, upper margins serrate; costa ending in or below the apex or occasionally very shortly excurrent; capsule when young and moist globose-pyriform, when dry and empty turbinate and constricted below mouth and spore sac; spores strongly papillose, 27-40μ in diameter, mature in spring. Carroll, Delaware, Elkhart, Hamilton, Hendricks, Henry, Jasper, Jefferson, Knox, Kosciusko, Lake, Lawrence, Madison, Marshall, Monroe, Noble, Owen, Parke, Perry, Porter, Posey, Pulaski, Putnam, Randolph, St. Joseph, Scott, Steuben, *Switzerland, Tippecanoe, Wayne, Wells, and Whitley Counties.

TIMMIACEAE

Plants large, tufted, growing on damp soil, in rock crevices, and at bases of trees; leaves lance-linear, sheathing, costate, toothed above, cells frequently papillose, almost isodiametric in blade, elongate in sheath.

Timmia

T. megapolitana Hedw. (Figs. 11-13.) Plants 3-5 cm. high; leaves lance-linear, crisped when dry, spreading when wet, canaliculate, 5-10 mm. long, 1.0-1.5 mm. wide, sheathing at base, gradually narrowed to apex, costa forming ridge on back of leaf, upper margin strongly serrate with teeth usually composed of several cells, upper leaf cells 10-14μ in diameter, smooth to slightly papillose, rounded and somewhat collenchymatous; dry capsule suberect to horizontal, 1 mm. in diameter, 2.0-3.5 mm. long; peristome double, outer of 16 teeth, inner of 64 cilia with long spinose appendages, at base attached to a high membrane, above commonly grouped in twos or fours; spores 12-18μ in diameter,

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are drawn from A. J. Grout, Moss Flora of North America north of Mexico **2**: pl. 69 G (M. Fl.). (The figures in parentheses refer to these books.) *Ephemerum serratum* (M.H.M., fig. 64), Fig. 1. Gametophyte and sporophyte, enlarged. Fig. 2. Leaf, enlarged. *Nanomitrium Austinii* (M.H.M., fig. 63). Fig. 3. Gametophyte and sporophyte, enlarged. Fig. 4. Leaf, enlarged. *Aphanorhegma serratum* (Icon. Musc. pl. 57, reduced ½). Fig. 5. Gametophyte and sporophyte, enlarged. *Funaria flavicans* (M.H.M., fig. 98). Fig. 6. Urn, about x 5.5. *Funaria hygrometrica* (M.H.M., fig. 97). Fig. 7. Gametophyte and sporophyte, x 1. Fig. 8. Urn, enlarged. *Physcomitrium turbinatum* (M.H.M., fig. 96). Fig. 9. Gametophyte and sporophyte, x 2. Fig. 10. Capsule and calptra, x 7.5 *Timmia megapolitana* (M.H.M., pl. 43). Fig. 11. Gametophyte and sporophyte, enlarged. Fig. 12. Leaf apex, enlarged. Fig. 13. Portion of peristome, enlarged. *Aulacomnium heterostichum* (M.H.M., fig. 100). Fig. 14. Gametophyte and sporophyte, enlarged. Fig. 15. Leaf apex, enlarged. *Aulacomnium palustre* (M.H.M., figs. 101 and 102). Fig. 16. Portion of gametophytes with pseudopodia, naked and with clusters of leaf-like brood bodies at summit, x 2. Fig. 17. Leaf-like brood bodies, enlarged. Fig. 18. Leaf apex, x 1.5. *Bartramia pomiformis* (M.H.M., pl. 44). Fig. 19. Gametophyte and sporophyte, enlarged. Fig. 20. Leaf apex, enlarged. Fig. 21. Mature urn, enlarged. *Philonotis fontana* (M.H.M., fig. 103). Fig. 22. Gametophyte and sporophyte, x 0.5. Fig. 23. Portion of gametophyte showing whorled innovations, x 0.5. Fig. 24. Leaf, x 5. Fig. 25. Male head, x 5. Fig. 26. Urn, x 5. *Philonotis marchica* (M. Fl. **2**: pl. 69 G). Fig. 27. Leaf, x 10. Fig. 28. Leaf cells, x 300.

smooth to slightly papillose, maturing in late spring *Montgomery and Lake Counties.

AULACOMNIACEAE

Plants in dense or loose tufts; leaves decurrent, costa strong, ending near apex; upper leaf cells thick walled, a single papilla on upper and lower surface; capsules strongly and regularly wrinkled when dry.

Aulacomnium

1. Plants growing on rich moist soil in woods, especially at base of trees; leaves dense, elongate-ovate, erect, not crisped when dry, commonly obtuse and apiculate, up to 3 mm. long, upper margins strongly serrate; plants not bearing gemmae; upper leaf cells rounded or ellipsoidal; spores slightly papillose, 9-12μ in diameter, mature in early summer ..... *A. heterostichum*

   Plants growing in swamps and wet shaded hollows; leaves long-lanceolate, crisped when dry, acute to slenderly acuminate, up to 4 mm. long, margins slightly to distinctly serrulate near apex, revolute below; upper leaf cells angular, sinuose-walled; pseudopodia up to 5 mm. long, naked or with minute ecostate leaf-like brood bodies in a cluster at upper end; spores smooth, 10-12μ in diameter, mature in early summer ..... (Ribbed Bog Moss) *A. palustre*

A. heterostichum (Hedw.) Br. & Sch. (Figs. 14-15.) Allen, Brown, Carroll, Clark, Crawford, Delaware, Fountain, Harrison, Jefferson, Knox, Lake, Lagrange, LaPorte, Lawrence, Monroe, Montgomery, Morgan, Owen, Parke, Perry, Porter, Posey, Putnam, Steuben, Warren, and Wayne Counties.

A. palustre (Web. & Mohr.) Schwaegr. (Figs. 16-18.) Allen, Cass, Delaware, Hamilton, Jasper, Jefferson, Kosciusko, Marshall, Lagrange, Lake, LaPorte, Noble, Parke, Perry, and Porter Counties.

BARTRAMIACEAE

Plants commonly in deep tufts, growing on soil or rocks in moist shaded places; leaves strongly costate to near the apex or long-excurrent, acute, margins usually serrate; capsules globose to ovoid, usually unsymmetric and without a neck, regularly plicate or deeply furrowed when dry; peristome double.

1. Stems frequently with a whorl of branches near the ends; leaves ovate-lanceolate to lanceolate-triangular; costa percurrent to shortly excurrent or spinulose-excurrent; cilia present in inner peristome ..... *Philonotis* .. 2

   Stems branched but not in whorls; leaves elongate-lanceolate to linear-lanceolate, canaliculate, frequently crisped when dry; costa excurrent to a terete, spinulose point; cilia of inner peristome rudimentary or lacking . (Apple Moss) *Bartramia pomiformis*

2. Leaves concave with one or two folds on either side of the costa; margins strongly revolute, doubly serrate; upper leaf cells not conspicuously parallel, papillose at lower end of cell, occasionally at both ends ..... *Philonotis fontana*

Leaves slightly concave with no apparent folds on either side of costa; margins plane or revolute, singly serrate; upper leaf cells parallel, papillose at upper ends ..... *Philonotis marchica*

Bartramia

B. pomiformis Hedw. (Figs. 19-21.) Allen, Brown, Clark, Crawford, Dubois, Fountain, Jasper, Jefferson, Lagrange, Lake, LaPorte, Lawrence, Martin, Monroe, Montgomery, Owen, Parke, Perry, Porter, Putnam, Steuben, Warren, Washington, and Wayne Counties.

Philonotis

P. fontana Brid. (Figs. 22-26.) Elkhart and Lagrange Counties.

P. marchica (Willd.) Brid. (Figs. 27-28.) Jefferson, Monroe, Putnam, and *Wayne Counties.

I consider the specimens of *P. Muhlenbergii* (Schw.) Brid., cited by T. G. Yuncker in Proc. Ind. Acad. Sci. **30**:236. 1920, to be *P. marchica* (Willd.) Brid.

Observations on the Stomatal Structure of *Ilex Opaca*

J. P. McMenamin, DePauw University

An anatomical study of the leaves of twenty-two shrub-bog species collected in North Carolina pocosins revealed several structural peculiarities in the leaf of the American holly, *Ilex opaca*, Ait. The guard cells of this species were unique among those of the twenty-two species studied in that they were the only guard cells whose walls took such lignin dyes as safranin and crystal violet.

In surveying literature for any previous work on this leaf, nothing was found. Solereder, in his *Systematic Anatomy of the Dicotyledons*, did not mention *Ilex opaca* but made the following statements concerning the holly family as a whole: "Stomata are found only on the lower side of the leaf; special subsidiary cells are wanting. . . . . The neighbouring cells of the stomata in some cases bear slight resemblance to subsidiary cells, e. g. *I. Paraguariensis*." These statements are of special interest because the guard cells of *Ilex opaca* appear to have special subsidiary cells.

The purpose of this paper, then, is to present a somewhat detailed study of the stomatal aparatus of this species, pointing out the interesting structural features.

The material examined came from trees in North Carolina, Ohio, and Indiana. Some of these trees were growing in bog water; others were growing in comparatively dry situations. Use was made of leaves that had been put through the paraffin process and various stain combinations. Microtomed paradermal and cross sections from fresh leaves were also studied. Cell wall structure was microanalyzed by various solubility and staining reactions.

The stomata of this leaf when examined on the lower epidermis at a low magnification appear to be nothing different from the ordinary dicot type. Yet, what could be taken on first sight for guard cells and a pore will be found to be raised parts of the cuticular covering. Each stomate is covered by a layer of cutin which extends out over the true pore in the manner of an oval dome with a slit in the ceiling of its long axis. The cuticular margins of the slit are usually jagged. As shown in figure 1, this oval dome is encircled with an irregular cuticular ridge which gives the appearance of a rampart surrounding the dome, a feature occasionally found in the *Ilicineae* according to Solereder.

The guard cells when brought into paradermal focus appear to be the familiar bean-shaped cells. In longitudinal and cross sections their top and bottom walls are quite thick, while the rounded, slightly enlarged ends of the cells have thin walls. The thickening of the bottom wall is not usually extended to the ends but is more confined to the pore length of the cells. Longitudinal views showing this may be seen in figures 4 and 5. In figure 4 is represented one guard cell cut longitudinally through the pore revealing how the cutin from the dome extends inward through the

pore over that part of the guard cells as a lining of the opening. The lumen of the guard cells is greatest at the ends. These cells though covered with a thick cutin layer are not sunken in relation to the other epidermal cells, but are slightly raised being partially supported by a ring of four to six, comparatively large, thin-walled epidermal cells, as seen in figure 2.

The cells of this ring are so different in size, shape, and wall thickness from epidermal cells that they appear to be special subsidiary cells. They may be encircled with one or two rings of narrower cells that appear to be a transition towards the thick-walled epidermal cells. Figure 3 was drawn from a paradermal section and represents the kind of view obtained looking from the spongy layer out through the lower epidermis. The guard cells are hidden in this view by the overlapping thin-walled subsidiary cells. In figure 2 two guard cells, represented by the heavy lines, are seen as they appear in focus just within the cutin layer. The two concentric rings of broken lines outside of the guard cells indicate the position of the cuticular rampart which was referred to before.

The thick-walled epidermal cells are shallow in depth compared with the extent of their lengths and widths. Their sides and ends protrude with curves that give the walls a serpentine appearance in paradermal sections. Especially noticeable in such sections is the pitting of the outer wall. Numerous pits extend into the cutin layer. According to Solereder pitting of this type is rare in leaf structure.

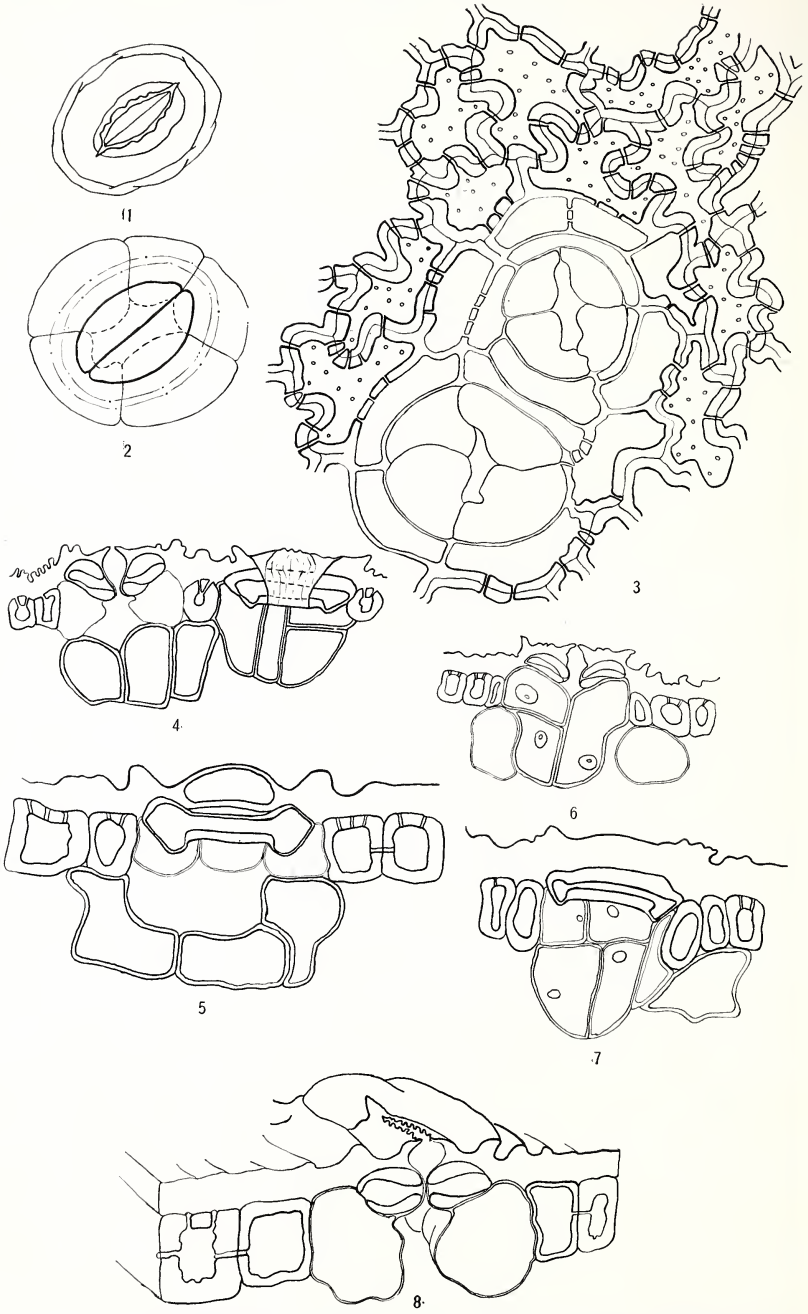
In order to determine something about the chemical nature of the wall structure, of the guard cells especially, staining and solubility tests were made and the following results obtained.

Lignin: Fresh sections showed distinctly positive reactions for the Maulé and phloroglucin tests in the thick walls of the guard cells and epidermal cells but negative reactions for the thin walls of the large cells adjacent to the guard cells. Sections were delignified and these two tests again applied. Where positive reactions occurred before, negative results now confirmed the first tests.

Cellulose: The chlorozinc-iodide and hydrocellulose tests gave no distinct indication of cellulose until the lignin, pectin, and cutin were removed from the cell walls. These three substances masked the cellulose thoroughly enough to prevent its dissolving in cuprammonia until they themselves were removed.

Pectin: Two staining tests, ruthenium red and methylene blue, when applied to delignified sections revealed a comparatively heavy concentration of pectin throughout the thickened wall of the guard cells, but little, if any, in the thin walls of the adjacent cells. These results were checked by applying the same stains to sections from which the pectin had been removed.

Cutin: Sudan III was used to bring out any less apparent areas of cutinization. This gave indications of the cutin extending over the areas of guard cell walls forming the pore. The thin walls of the cells adjacent to the guard cells also appeared to be thinly cutinized.



All of the drawings except Fig. 8 were made by camera lucida and represent, here, a magnification of 530 X. Fig. 1. Surface view of a stomate. Fig. 2. Paradermal view of the same stomate just beneath the cutin layer, showing the closed guard cells partly supported by a ring of subsidiary cells. Fig. 3. Paradermal view of epidermal and subsidiary cells as seen from the spongy layer

This wall microanalysis made it clear that the guard cell walls are more like epidermal cell walls in chemical composition and structure than like the thin-walled, large adjacent cells which are so different from both the epidermal and guard cells in form and structure. It seems fitting, then, to refer to these thin-walled cells as subsidiary cells.

It may be expected that these subsidiaries aid in the mechanical functioning of the guard cells. Hinges, which are useful in this respect are noticeable in cross sections. One unusual fact concerning these subsidiaries was evident in sections from older leaves. Not infrequently there was noticed a plugging of the inner stomatal chamber, which must have been affected by one or two divisions of the subsidiary cells. The walls of these plugging cells are usually thicker than the ordinary subsidiary cell wall, and also partly lignified.

Outlines of wall structure in paradermal sections were more distinct when fresh sections were mounted in a salt solution. Plasmolysis of subsidiary and epidermal cell protoplasts was clear. The guard cells, however, revealed no internal changes. This may have been partly because they were hidden by the subsidiaries through which one must focus, or, more likely, because of their small lumen.

It should be pointed out that no new type of stomatal apparatus is presented here, as the stomatal mechanism of *Ilex opaca* would be considered much the same as Schwendener's *Helleborus* type referred to by Copeland[1]. Nevertheless, the cuticular covering, the cutin of the dome extending internally through the stomatal pore as a lining even in the thin walls of the subsidiary cells, the partially lignified guard cell walls, and the plugged stomatal chambers, all present an interesting aspect of xeromorphy in the stomatal mechanism.

[1] Copeland, E. B. The mechanism of the stomata. Ann. Bot. **16**:327-364. 1902.

Summary

The stomatal structure in the leaves of *Ilex opaca* was studied and the following features pointed out as exhibiting xeromorphy:

(1) Guard cells with differentially lignified walls.

(2) Stomatal pores lined with a thin internal extension of the cuticular dome.

(3) Thin-walled, slightly cutinized cells adjacent to the guard cells, which appear to be subsidiaries considering their location, form, and wall structure.

(4) Plugged stomatal chambers apparently caused by the division and growth of some subsidiary cells.

I wish to express my thanks to Dr. T. G. Yuncker of DePauw University, and Drs. B. W. Wells and D. B. Anderson of North Carolina State College for their kind help and advice during the progress of this study.

looking out through the lower epidermis. Fig. 4. Sectional views through two adjacent stomata. Fig. 5. Sectional view revealing a longitudinal cut through one guard cell. Figs. 6 and 7. Two sectional views of stomata plugged by apparent division of subsidiary cells. Fig. 8. A three-dimensional concept of a cross section through a stomate and nearby cells.

Preliminary Report on a Coal Ball Flora from Indiana

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Occurrence

Calcareous, dolomitic, or pyritic nodules occasionally found just below the roof shales of coal seams are commonly called "coal balls"; and frequently they contain portions of fossil plants in good states of preservation with little distortion from compression. Coal balls of the calcareous type were collected by the author in June, 1938, at the Rosebud Mine, two miles north of Petersburg, in Pike County, Indiana.[1] The coal seam bearing these nodules has been assigned to upper Coal No. 5 of the Indiana series.[2] Coal No. 5 is equivalent to the upper Allegheny group of the Appalachian Carboniferous. It is noteworthy that this coal is composed almost exclusively of vitrain and durain. In the Rosebud slope-shaft mine the seam averages approximately 5 feet in thickness, and the coal balls were found in the upper 6 inches next to a hard, gray-brown roof shale. The coal balls range in size from one inch to 8 inches in diameter, the smaller specimens being roughly spherical and the larger ones more or less discoidal. Calcium carbonate is the principal constituent of the coal balls containing fossil plants, although a few showed low concentrations of pyrite in the form of minute crystals. Several larger nodules of pure pyrite were collected, but proved to be practically sterile of recognizable plant remains. Large "ironstone" concretions devoid of fossils occur frequently in the roof shales of this locality, but coal balls bearing plant remains suitable for study were found only in one area of approximately 200 square feet. One hundred sixty specimens were collected, and many of these contain several coal balls solidly imbedded in coal. The sawed pieces have been inserted in the Paleobotanical Collections of the Harvard Botanical Museum and bear numbers from 39001 to 39158, and from 39198 to 39329.

Preparation of the material

For this reconnaissance survey of this coal ball flora, the nodules were first sectioned at random by means of a carborundum disc saw. Then the sawed surfaces were ground flat on a lapidary, and nitrocellulose peels were made from these surfaces according to the method of Darrah.[3]

[1] The occurrence of coal balls at this locality was brought to the author's attention by Dr. C. B. Read of the National Museum.

[2] Dr. Ralph Esary, personal communication, October 19, 1940. The nomenclature for the Indiana coal series was established by G. H. Ashley in the *Twenty-third Annual Report of the Indiana Department of Geology and Natural Resources*, 1899, pp. 1-1741.

[3] Darrah, W. C. 1936: The peel method in paleobotany. *Bot. Mus. Leaflets. Harvard Univ.* **4**(5):69-83. Also, *idem.* 1939: Textbook of Paleobotany. D. Appleton-Century, New York. Pp. 13-16.

In many of the specimens the limestone had become somewhat "rotten", probably because of the constant passage of ground water through the roof of the mine gallery. On all of the specimens only a very low concentration (3-5%) of hydrochloric acid could be used for etching the ground surfaces.

The nitrocellulose peels were first examined under a 10-power binocular dissecting microscope. The sections worthy of study were cut out and mounted on microscope slides in damar, in order to facilitate observations under higher powers.

The detailed study of this coal ball flora will involve investigations of the significant plant remains by serial sections (i. e. the preparation of consecutive peels at evenly spaced intervals through the specimen). In many cases differently oriented saw cuts should confirm the identifications of plant remains disclosed by this preliminary survey.

Description of the flora

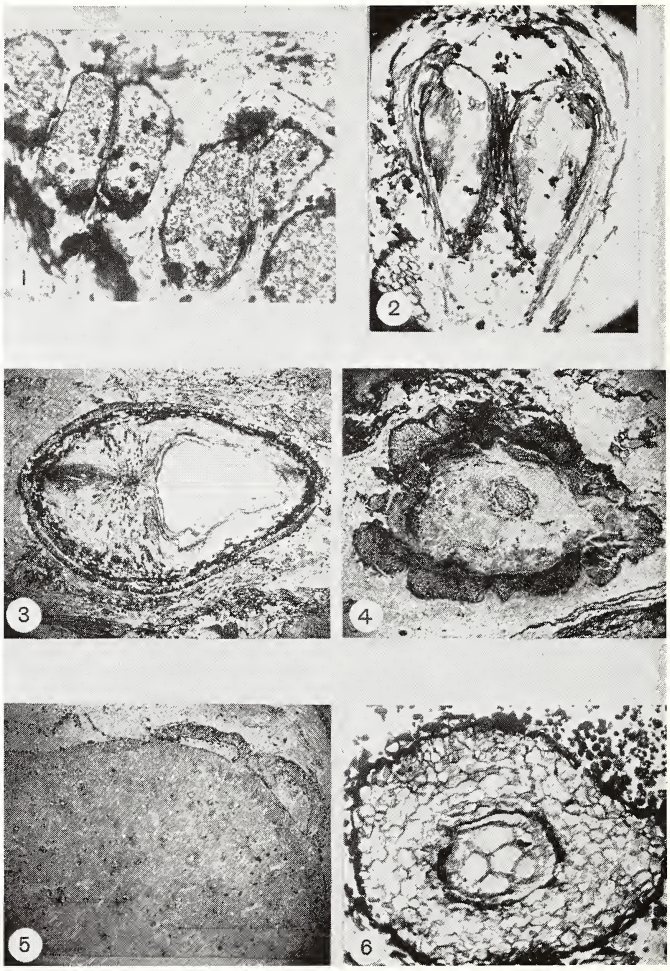
The following list enumerates the plants and plant parts identified during the reconnaissance survey of this flora:

LYCOPSIDA
- Lepidodendrales
  - *Lepidodendron* group *selaginoides* Sternberg (= *L. vasculare* Binney)
  - *Lepidostrobus* sp.
  - *Lepidocarpon glabrum* Darrah
  - *Lepidodendron* leaves
  - Lepidodendrid megaspores
  - " microspores
  - Stigmarian rootlets

SPHENOPSIDA
- Sphenophyllales
  - *Sphenophyllum* cf. *plurifoliatum* Williamson and Scott
- Equisetales
  - *Calamites* sp.

PTEROPSIDA
- Filicinae
  - *Botryopteris* sp.
  - *Asterotheca* sp.
  - *Myriotheca* sp.
  - *Ptychocarpus* sp.
  - *Psaronius*
  - *Stipitopteris* sp.
  - *Pecopteris villosa* Brongn.
- Gymnospermae
  - Pteridospermae
    - *Myeloxylon*
    - *Neuropteris* cf. group *rarinervis* Bunb'y
  - Cordaitales
    - *Cordaicarpus* ? sp.

The *Lepidodendron* fragments, especially stems and leaf bases, are conspicuous by their numbers in this material. The stems have been assigned to *L. selaginoides* Sternberg (= *L. vasculare* Binney) since the primary wood extends to the center of the stele where short tracheids



EXPLANATION OF PLATE I

Fig. 1. Pecopterid sporangia of a type which is very common in this flora. X 36.

Fig. 2. *Ptychocarpus* sp. Longitudinal section. X 28.

Fig. 3. *Lepidocarpon glabrum* Darrah. Longitudinal section. X 7.

Fig. 4. *Lepidodendron* group *selaginoides* Sternberg (= *L. vasculare* Binney). Transverse section of stem. X 5.

Fig. 5. Portion of *Myeloxylon* petiole with pinnule in attachment. Transverse section. X 6.

Fig. 6. An ultimate petiole of *Botryopteris* sp. Transverse section. X 37.

having characteristic reticulate thickenings are mixed with parenchymatous cells. To the extent that they are displayed in these specimens, the other definitive characters conform to the *selaginoides* group (Plate I, Fig. 4). All of the specimens are small branches 8 to 25 mm in diameter including the leaf bases. A few show the beginnings of secondary wood development.

Two specimens of *Lepidostrobus* have been found. One is a very small immature strobilus in which the fertile portions of the sporophylls were just beginning to develop. The other is a fragment of the mature strobilus of which several microsporophylls and their spores are well preserved. In this piece the microspores average 93 μ in diameter; each possesses an equatorial "wing" the margin of which is crenulate, and the surface of each spore bears a coarse reticulum which is more delicate near the pronounced triradiate scar. Neither of these specimens of *Lepidostrobus* are sufficiently well preserved to be assigned to species.

One specimen of *Lepidocarpon glabrum* Darrah was found (Plate I, Fig. 3). This seed is 7.8 mm in length and 4.2 mm in width, thus slightly less elongate than Darrah's type.[4] Fortunately the seed happened to be cut in a median plane approximately 1 mm to the side of the central vascular strand. The preservation is unusually good, and particularly well shown is the vascularization. At three-quarters of the way from the proximal end of the seed to the megagametophyte the central vascular strand sends out two branches at right angles to the plane of the section shown in figure 3; just distal to this point two more vascular branches are given off in the plane of the section. These latter two strands will be seen to follow closely the proximal margin of the megagametophyte, and it is likely that the other two strands at right angles to these are just as intimately associated with the megagametophyte. Miss Reed[5] described the structure of several seeds from coal balls collected in Coal No. 5 in southern Indiana and Illinois, but the *Lepidocarpon glabrum* form was not encountered in that material.

Numerous transverse sections of leaves of arborescent Lycopods were found. All contain only one leaf trace, and are therefore to be referred to *Lepidodendron* rather than *Sigillaria*, the leaf of which has two traces. The microspores and megaspores of Lepidodendrid types are abundant in many of the coal balls. Four of the broad-winged type of Lepidodendrid microspores drifted into the specimen of *Ptychocarpus* shown in figure 2. As in nearly all Lepidodendrid floras, Stigmarian rootlets are common, although poorly preserved, in these coal balls.

Stems of *Sphenophyllum* are frequent in this material. All but one may be referred to *S. plurifoliatum* Williamson and Scott. This one exception possesses a very small triarch stele with no secondary wood. The inner cortex has disappeared, but the outer cortex is composed of cells with very strong walls; and the stem has six conspicuous ridges. This specimen is probably a *Sphenophyllum* rootlet. The decorticated stems of *Calamites* are present in approximately the same abundance as

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[4] Darrah, W. C. 1941. The fossil flora of Iowa coal balls. IV. *Lepidocarpon*. *Bot. Mus. Leaflets. Harvard Univ.* **9**(5):85-100.

[5] Reed, Fredda D. 1939: Structure of some Carboniferous seeds from American coal fields. *Bot. Gaz.* **100**:769-787.

Sphenophyllum. The *Calamites* wood in these coal balls consistently has a large quantity of included pyrite crystals, and the preservation of cell wall details is poor.

The representatives of the true ferns in this flora belong to two groups, the Coenopterid genus *Botryopteris* and the presumably Marattiaceous *Pecopteris* complex. *Botryop'eris* is represented by a few very small "petioles" (i. e. axes of various parts of pinnae). These petioles average 2 mm in diameter, and each has a small circular protostele made up of tracheids with annular and scalariform thickenings (Plate I, Fig. 6). The cortex resembles very closely the type of cortex possessed by *B. americana* Graham, but this latter form is characterized by a trident-shaped stele and averages 4.8 mm in diameter.[6] It is probable that the *Botryopteris* petioles in the Indiana coal balls are ultimate axes of pinnae and are borne upon "primary" petioles such as *B. americana*. It is hoped that serial sections of these petioles will reveal the nature of their attachment. No Botryopterid sporangia have been found so far in these coal balls.

The members of the *Pecopteris* complex found in this flora are *Asterotheca* sp., *Myriotheca* sp., *Ptychocarpus* sp., *Psaronius*, *Stipitopteris* sp., and *Pecopteris villosa* Brongn. Sporangia are very abundant in this flora; and although nearly all lack attachment with other plant parts, most of them have been determined as Pecopterid (Plate I, Fig. 1) on the basis of the form and disposition of the sporangia and the characteristic spores.[7] Specimens of *Asterotheca* are numerous, but sporangia referable to *Myriotheca* are the most abundant of these fructifications. The determinations of the specimens of *Asterotheca* were made on the basis of the distinctive radiate disposition of the 4 to 7 sporangia in the synangial clusters and the shapes of the individual sporangia. All of these sporangia were devoid of spores. The reference of specimens to *Myriotheca* was made on the basis of the large numbers of sporangia regularly disposed within the groups and the profusion of spores of the type described by Sellards[8] for *Myriotheca*.

Two synangia resembling *Ptychocarpus* were revealed in the coal balls. The better specimen (Plate I, Fig. 2) conforms very closely to *Ptychocarpus unita* Brongn. in size, gross structure, and the disposition of the central column of dense tissue, as described by Graham.[9] This synangium is 1.7 mm long from the lamina to the distal end and 0.7 mm in diameter. However, close examination reveals that the sporangia are suspended by short peduncles from the lamina and that the synangium is sheathed in an extra integument which follows the contours of the

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[6] Graham, R. 1935: Pennsylvanian flora of Illinois as revealed in coal balls. II. *Bot. Gaz.* **97**:156-168. Darrah, W. C. 1941: The Coenopterid ferns in American coal balls. *Amer. Midl. Nat.* **25**:233-269.

[7] The author has recently isolated the spores from various accurately determined fructifications of Carboniferous plants in order to assist in determinations such as these.

[8] Sellards, E. H. 1902: On the fertile fronds of Crossotheca and Myriotheca, and on the spores of other carboniferous ferns, from Mazon Creek, Illinois. *Amer. Jour. Sci.* 4th ser. **14**:195-202.

[9] Graham, R. 1934: Pennsylvanian flora of Illinois as revealed in coal balls. I. *Bot. Gaz.* **95**:453-476.

synangium and has distally a sort of stoma guarded by reflexed hairs. Unfortunately with this specimen there are associated five different types of spores, none of which are the typical spores of *Ptychocarpus*. This specimen is provisionally referred to *Ptychocarpus* until more detailed study may definitely determine its characters and identity.

Psaronius, a Marattiaceous type of stem which usually bore Pecopteroid foliage, is represented in these coal balls by numerous fragments of the cortex. Four petioles of the genus *Stipitopteris* were discovered. The *Stipitopteris* petiole possesses a vascular bundle which has the shape of an "elongated horseshoe" in transverse section, and a leaf trace diverging from the bundle appears as an "isolated W-shaped segment within the outer band."[10] Lenz has shown that the bundle of this petiole conforms exactly with the shape of the bundle scars on the decorticated *Psaronius* stems known by the form-genus name *Caulopteris*. The specimens of *Stipitopteris* in the Indiana coal balls are oval in outline with the long axis extending through the leaf trace gap, and average 1.9 mm by 3.2 mm. The vascular bundles average 1.3 mm in greatest diameter. None of the petioles in this material show an isolated leaf trace. Protoxylem points are found on the two edges of the horseshoe-shaped stele, and two or three more occur on the inner side of the stele opposite the gap. The study of these petioles by serial sections will be necessary before they can be assigned to species.

In this material many pinnules occur. By far the greatest number of them have a "ram's horn" shape in transverse section, average 2.5 mm in breadth, and contain a leaf trace of the *Stipitopteris* type with the gap toward the upper surface of the lamina. Characteristic of most of these pinnules are the numerous hairs on the under surface of the lamina and on the prominent midrib. These pinnules have been assigned to *Pecopteris villosa* Brongn. and were probably originally attached to *Stipitopteris* petioles which were in turn attached to *Psaronius* stems.

Five petioles belonging to the form-genus *Myeloxylon* have been found in these coal balls, and a pinnule is in attachment with one of the petioles. In greatest diameter they range from 4.0 mm to 9.5 mm. The pinnule in attachment with one of the petioles (Plate I, Fig. 5) is the basal member of a pinna which was borne on this petiole and appears to conform with the pinnule type assigned to *Neuropteris*. In addition to the *Pecopteris* pinnules another type of pinnule occurs in considerable numbers. This latter type averages 4 mm in breadth, has a relatively thin lamina with no hairs on the under surface, and has a consistent layer of columnar heavy-walled cells immediately under the epidermis of the upper surface. Two of these pinnules chanced to be exposed in horizontal section so that the venation was revealed. The veins form a definite midrib through only the basal half of the pinnule; the lateral veins diverge from the mid-line at low angles, and they usually branch once, occasionally twice. These pinnules are ovate with the margins entire. Unfortunately the basal portions of neither of these pinnules were preserved, so the important characters of the mode of attachment to the petiole cannot be determined. One of this type pinnule was found

[10] Lenz, L. W. 1942: Contributions to our knowledge of American Carboniferous floras. III. Stipitopteris. *Annals Missouri Bot. Garden* **29**:59-68.

in attachment with a *Myeloxylon* petiole (Plate I, Fig. 5). It seems reasonable to assign this pinnule type to Neuropteris group *rarinervis* Bunb'y, and to assume that they probably were in attachment with *Myeloxylon* petioles as parts of Pteridospermous plants.

A seed-like structure which may possibly be an immature *Cordaicarpus* was found although no other Cordaitean material was discovered. This structure consists of an outer bag-like sclerenchyma coat and enclosing a heart-shaped cellular body which is half enclosed in a firm integument. Within the heart-shaped body is a body of similar form which appears to be non-cellular. The entire structure measures 1.15 mm in length, 0.90 mm wide at the broadest part, and 0.45 mm wide at the tip. The mode of attachment is not revealed. The fact that this seed structure is bilaterally symmetrical indicates that it belongs to the primitive gymnosperms known as Cordaitales and can best be referred to the form-genus *Cordaicarpus*.

Conclusion

Most abundant of the plant parts in these coal balls are fern pinnules, detached fern sporangia, and fragments of *Lepidodendron* stems and leaves. Stems of *Calamites* are just as frequent as the complete stems of *Lepidodendron*. Specimens of *Sphenophyllum* and *Myeloxylon* are less common, and the only evidence of members of the Cordaitales rests upon the single dubious specimen of *Cordaicarpus*. Therefore, on the basis of this preliminary survey, this assemblage of plants must be recognized as a Lepidodendron-Calamites-Fern flora in which specimens of *Sphenophyllum* and Pteridosperms are members of a minor element. It must be borne in mind, however, that these coal balls taken from a very small area may possibly not offer a flora that is strictly representative of the horizon.

In general, this coal ball flora from upper Coal No. 5 in Indiana is very similar in generic composition to the coal ball floras from Illinois. It may be compared also with the flora from Frontenac, Kansas, reported by Darrah.[11] In the Frontenac coal balls, on the other hand, the presence of Cordaitean material, although rare, gives the flora a somewhat different aspect, as if it were transitional (in time) between the Lepidondendrid floras of Illinois and Indiana and the Cordaitean floras of Iowa coal balls.[11] It remains to be shown in the Mid-continent Carboniferous whether such transitions between floras are to be recognized as phenomena of time or of space or both.

The author wishes to express his sincere appreciation and thanks to: Mr. Eli Hendricks, owner of the Rosebud Mine, for the privilege of collecting the coal balls and for valuable assistance in the field; to Mr. Frederick O. Thompson of Des Moines, Iowa, for funds for the preparation of the nitrocellulose peels; and to Mr. W. C. Darrah, Curator of Paleobotany at the Harvard Botanical Museum, for the use of reference materials and for indispensable personal guidance in this work.

[11] Darrah, W. C. 1941: Studies of American coal balls. *Amer. Jour., Sci.* **239**:33-53.

Distribution by Altitude of Two Species of Lemanea in Tennessee

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During the spring of 1942, twelve samples of Lemanea from Tennessee were sent to the writer by Herman Silva of the University of Tennessee. All of the material was collected at various elevations from Little Pigeon River in Sevier County. The alga was attached to clastic siliceous rocks of Cambrian age. Some samples were collected in August and September of 1941, while others were obtained in May, 1942. The collector left, at that time, for military service making it impossible to obtain additional collections.

Very few specimens of Lemanea have been reported for Tennessee. Atkinson (1) described material from the Carolinas, back in 1890, as a new species *Lemanea australis* and assumed that other material from the southern states probably belonged to this species. The new collections of the genus made by Silva have proved to contain two species which belong to different subgenera and are readily distinguished (2). One of these is the *Lemanea australis* Atk. This is one of the few authentic reports for this species since it was first described in 1890. The species can be recognized during the spring by its peculiar Chantransia filaments, which are small in diameter near the base and gradually become much larger in diameter nearer the tip. The diameter at the tip may be three or more times that at the base (Fig. 1). The sexual shoot of this species is characterized as having wide regular antheridial rings near the tip, with narrower, less regular rings nearer the base (Fig. 2).

The other species of Lemanea found in Silva's collection is *Lemanea fucina* Bory. This species is common in New England and Canada and is present to some extent in the mountainous parts of the more southern states. It differs from *L. australis* in having an inconspicuous Chantransia stage with filaments of uniform diameter, and a sexual strand with antheridia in papillae instead of in rings at the nodes (Fig. 3).

The samples of Lemanea were collected by Silva in Little Pigeon River at five different elevations, ranging from 2,600 feet down to 1,700 feet. *L. austrialis* was found to be present at all altitudes, being abundant in the collections made at 2,500, 1,900, 1,750 and 1,700 feet and absent (none in one collection) to rare (one strand only in another collection) at 2,600 feet. *L. fucina*, in contrast, was abundant in the samples collected at 2,600 feet, absent in those at 2,500 feet, with a small amount at 1,900 feet and one strand only in the sample taken at 1,750 feet. It was absent in the 1,700 foot collection (Table 1).

Thus, it would appear that the southern species, *L. australis*, was common in the stream from 2,500 feet down to 1,700 feet while the northern species was abundant only at 2,600 feet and was absent entirely at the lowest level where collections were made.

Due to the infrequency with which collections of Lemanea are made, it has seemed worthwhile to report this apparent difference in distribution by altitude of two species of the genus, even though conclusions drawn from such a small number of samples are subject to error.

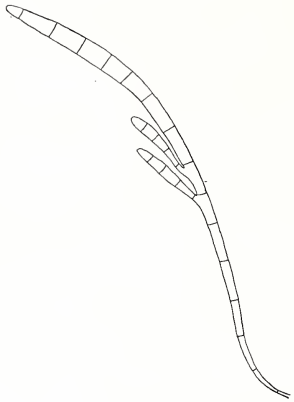

Fig. 1.

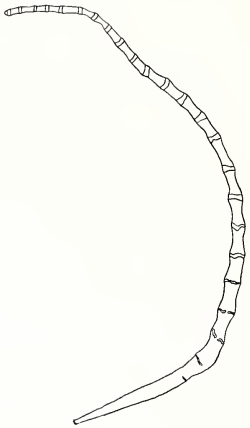

Fig. 2.

TABLE I.—Distribution by Altitude of **Lemanea fucina** and **Lemanea australis** in Little Pigeon River, Tennessee

Elevation in feet	L. fucina	L. australis
2,600	xxxxx	x
2,500	0	xxxxx
1,900	xxx	xxxxx
1,750	x	xxxxx
1,700	0	xxxxx

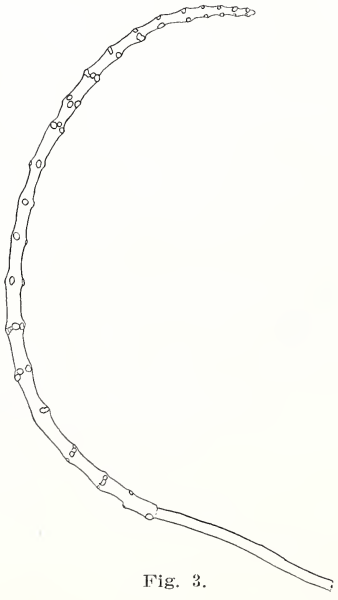

Fig. 3.

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1. Atkinson, G. F. Monograph of the Lemaneaceae of the United States. Ann. Bot. **4**:177-230. 1890.

2. Palmer, C. M. A study of Lemanea in Indiana with notes on its distribution in North America. Butler Univ. Bot. Stud. **5**:1-26. 1941.

A List of Myxophyceae from Wayne County, Indiana

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It is interesting to note that the first list of algae for the state of Indiana came from Wayne County. This list by E. T. Cox in 1876 (3) included the genus *Oscillatoria*, and a number of genera of desmids and diatoms. The next contribution to Wayne County algae was that of Ruth Trueblood in 1903 (13). In this paper she describes 36 species including 6 species of *Myxophyceae*. A more comprehensive study was that of M. S. Markle in 1910 (10). This paper describes 46 species including 11 species of *Myxophyceae*. More recent records are included in the investigations of Daily (4), and Drouet (5).

The collections listed here were made in the years 1939 to 1942 inclusive. Some early collections were made by Dr. M. S. Markle of Earlham College, later ones being made by the writer and some jointly with Dr. Markle. Many of the collections have been made in the vicinity of Richmond, while some have been made at other points in the county. The collections have all been examined and determined by Dr. Francis Drouet of the Field Museum of Natural History. The specimens of *Chroococcaceae* have been studied in large part by William A. Daily, and these species were cited by him in his study of that family (4).

In this list of 61 forms there are 3 varieties, 30 species, and 3 genera of *Myxophyceae* which are new records for Indiana. In looking over the published lists of *Myxophyceae* from Indiana the scarcity of soil and rock forms is particularly noticeable. In collections from Wayne County an especial effort has been made to collect forms from these habitats.

Since there are abundant outcroppings of rock throughout the southeastern part of the county, these provide a wide variety of habitats. Collections have been made from many places at Thistlethwaite's Falls on the Whitewater River, and from many points on the rock ledges through the length of the gorge to the south. Whitewater gorge at Richmond is about 3 miles long, 200-300 feet wide and up to 100 feet or more in depth (11, 12). The rock here is the Hudson River limestone series of the Ordivician. Collections have been made from the ledges at the Middleborough quarry (Clinton or Niagara series of limestone) 3 miles northeast of Richmond; the rocks at Tufa Falls just south of the Elliott's Mills bog 2 miles southeast of Richmond; and at Elkhorn Falls 3 miles southeast of Richmond. Another rich source for rock forms has been the interiors of several large stone tunnels at the Pennsylvania R.R. yards just northeast of Richmond. Such a habitat was the only source for *Pleurocapsa varia*. This was found in the crevices of the stonework of one tunnel, and in another it was growing as large circular colonies some 8-10 cm. in diameter on the smooth moist surface of the concrete wall. The only station for *Schizothrix lateritia* was in the calcareous incrustations in the crevices of the stonework of a small tunnel north of Richmond. In all of these tunnels the light intensity was quite

low. Planktonic species were mostly collected at Lake Wehi just south of Germantown, in the drainage pool of the ice company spray pond at Richmond, and at various places in the Whitewater River.

Species found chiefly on alternately wet and dry rock or clay-shale in the Whitewater gorge were *Hassallia byssoidea, Schizothrix purpurascens, Microcoleus acutissimus, Plectonema purpureum,* and *Phormidium incrustatum.* The species of *Schizothrix* listed here were almost entirely restricted to rock habitats or to calcareos material. Frequently these species were associated with *Calothrix parietina. Nostoc microscopicum* has been found as minute dark discolorations on some of the projecting rock slabs above Thistlethwaite's Falls in very dry exposed situations—in such habitats as the lichens, *Caloplaca cerina* and *Lecanora Hageni,* occur. In summer and fall many of these habitats are quite dry, but during the winter months these rock ledges are quite moist. In the areas at the waterfalls many more rock species are found.

The only location for *Nostoc humifusum* was on the clay-shale under the shade of spreading shrubs of *Rhus aromatica* growing along the upper ledges of Whitewater gorge. Here rather extensive growths were found. Here as well as in other places on the rock ledges the species of *Myxophyceae* together with mosses appeared to form the pioneer stages in these bare areas. It is probable that such pioneer stages of succession may occur at many points on the bare areas in the gorge. Such algal succession for denuded soil areas in Kansas and Oklahoma has been described by Booth (1).

Species of *Cylindrospermum* were perhaps the most frequently collected soil forms—especially *C. muscicola.* The one station for *C. catenatum* was in a small depression on the moist soil in Elliott's Mills bog. In the genus *Nostoc, N. Muscorum* was the most frequently collected soil species. Both *N. ellipsosporum* and *N. spongiiforme* were found on moist sand or sandy soil near streams.

A large number of collections were made at the spray pond of the Crystal Ice Co. at Richmond. The spray pond, built in 1916, serves to cool the water used in the ice manufacturing machinery. The large area, 72 by 44 feet, is divided into two parts. The western half is an expanse of concrete that serves as a drain for the pool occupying the eastern half. Some of the sprays operate over the concrete area and some extend over the pool.

The water is slightly thermal—especially during the summer months. According to data supplied the writer the water from the sprays is quite warm, 46° C., approaching 35-40° C. where it reaches the drainage area. The water in the pool may reach a temperature of 41° C. The water in the pool is quite alkaline. Samples determined with a hydrogen electrode gave a pH value of 8.5.

The whole area is unique in that the growths of many of the species of *Myxophyceae* found there are quite extensive. Many of the species have a rather definite zonation in the area. The one species which is perhaps the most abundant there is *Lyngbya purpurea.* This species is of interest because of its rarity. It was first described by J. D. Hooker and W. H. Harvey in 1845 from Kerguelen in the south Indian ocean near Antarctica (8, 9). There it was first found in rivulets covering mosses

and water plants at an altitude of 3,700 feet. The authors believed it belonged to the genus *Oscillatoria* and so named it *O. purpurea*. Maurice Gomont in his classical *Monographie des Oscillariées* (7) placed the species in the genus *Lyngbya*. He based his determination on the original material in the Dublin Museum. He measured the trichomes and in addition noted that the purple color, for which the species had been named, had entirely disappeared from the specimen. The only other published record which the writer has located is that of G. S. West in 1907 from Lake Tanganyika in central Africa (6, 14).

The species is characterized by its small size, 1.4 to 1.8 microns, and its purple to reddish-orange (or even blue-green) color. It generally has been found attached to a substratum, and growing in very dense tufts. At the spray pond the species covers many square feet of the moist concrete of the drainage area. Here it has been found growing in association with *Calothrix parietina*. In these incrusted mats the true purplish color of the species is evident. Elsewhere on the iron pipes and the concrete posts near the pool, the species is orange in color in the surface masses; while the undersurface masses are blue-green. In September, 1942 numerous floating masses of this species were observed in Lake Wehi.

At the spray pond the growth of the *Lyngbya* was almost entirely restricted to the areas kept moist by the sprays, and where water was standing when the sprays were functioning. In an outer zone at the south end where the amount and movement of the water was not as great there were extensive growths of *Scytonema figuratum*. In this more aerial habitat this species grew in a pure form in spongy mats 3 to 4 mm. thick. On the outer limits of the area where only occasionally wind-blown spray falls the flora is considerably different. Here in this area of washed-in gravel and debris on the outer limits of the spray pond such species as *Microcoleus vaginatus, Phormidium autumnale, Schizothrix lardacea* and *Chroococcus rufescens* were growing.

The spray pond pool was about 4½ feet deep with an extensive deposit of sediment in the bottom. The sediment was almost entirely made up of algae. Species found here included *Plectonema Nostocorum, Lyngbya aestuarii, Oscillatoria tenuis* var. *tergestina, Chroococcus turgidus*, and *Merismopoedia glauca*. Numerous floating masses in the pool included *Oscillatoria limosa, O. princeps, O. splendida, Chroococcus turgidus*, and *M. glauca*. In the drainage ditch from the pool in the moving water were extensive growths of *Phormidium subfuscum* var. *Joannianum*. Conditions in this pool approach the conditions as described by Copeland for Yellowstone thermal *Myxophyceae* (2). He found that the greater number of species occurred in alkaline situations at pH 8.0, and at a temperature of about 35° C.

Specimens of all species listed here have been placed in the herbarium of the Field Museum of Natural History in Chicago. Duplicates of these have been placed in the Earlham College herbarium in Richmond. The collection numbers when not otherwise designated refer to those of the writer. Those species listed from the spray pond are all from the spray pond of the Crystal Ice Co. at Richmond. Those species marked with an asterisk are new records for the state of Indiana.

Chroococcaceae

Chroococcus rufescens (Kütz.) Näg.—With *Schizothrix lardacea* on gravel at edge of ice company spray pond at Richmond, *30*, Aug. 13, 1940. With *Anacystis rupestris* on nearly submerged rocks at Elkhorn Falls, *207*, Sept. 7, 1940. With *A. marginata* in sediment at edge of Lake Wehi, *Markle & King 737*, Sept. 7, 1942. In algal masses attached to floating cat-tail stump in Lake Wehi, *Markle & King 739*, Sept. 7, 1942. In floating masses in Lake Wehi, *Markle & King 757*, Sept. 7, 1942.

Chroococcus turgidus (Kütz.) Näg.—With *Oscillatoria limosa* and *O. princeps* in ice company spray pond at Richmond, *50*, Aug. 15, 1940. With *Anacystis Peniocystis* and *Schizothrix fuscescens* on wall of cave at Elkhorn Falls, *201*, Sept. 7, 1940. In sediment from bottom of spray pond at Richmond, *371*, Nov. 10, 1940.

Pleurocapsa varia (A. Br.) Drouet & Daily—With *Plectonema Nostocorum* in calcareous material in the crevices of stonework, inside wall of R.R. tunnel ½ mile north of Richmond (near Union Pike), *61*, *62*, Aug. 18, 1940. On smooth concrete wall in north end of south tunnel of Pennsylvania R.R. yards (near Morton Lake) east of Richmond, *76*, *77*, Aug. 29, 1940.

Merismopoedia glauca (Ehrenb.) Kütz.—In sediment from pool of spray pond, *34*, Aug. 22, 1940.

Anacystis marginata Menegh.—With *Chroococcus rufescens* in sediment at edge of Lake Wehi, *Markle & King 737*, Sept. 7, 1942. Identified since the publication of Daily's paper (4).

Anacystis rupestris (Lyngb.) Drouet & Daily—With *Plectonema roseolum* and *Oscillatoria granulata* in laboratory culture at Earlham College, *Markle 4*, 1939. On moist soil and among mosses at School Street gravel pit ½ mile west of Richmond, *12*, *13*, July 9, 1940. With *Chroococcus rufescens* on nearly submerged rocks at Elkhorn Falls, *207*, *209*, Sept. 7, 1940. With *Microcoleus vaginatus* on moist soil of swamp just south of Lake Wehi, *Markle & King 738*, Sept. 7, 1942. With *Schizothrix fuscescens* in crevices of cliff at Elkhorn Falls, *203*, Sept. 7, 1940.

Anacystis Peniocystis (Kütz.) Drouet & Daily—With *Chroococcus turgidus* and *Schizothrix fuscescens* on wall of cave at Elkhorn Falls, *201*, Sept. 7, 1940.

Chamaesiphonaceae

**Chamaesiphon polonicus* (Rostaf.) Hansg.—Scraped from the fountain at east side of courthouse at Richmond, *160a*, Nov. 10, 1940.

Stigonemataceae

**Fischerella ambigua* (B.&F.) Gom.—On rocks of north ledge of bluffs (near spring) at Thistlethwaite's Falls, *39*, Aug. 14, 1940. New genus for Indiana.

Nostocaceae

Nostoc Muscorum B.&F.—With *Cylindrospermum majus* on soil in swamp, Friedline farm north of Richmond, *10*, July 7, 1940. On soil by entrance to biology laboratory (Bundy Hall), Earlham College, *17*, Aug. 1, 1940. On moist soil of recently exposed swamp bed in large swamp north of Williamsburg, *83*, Aug., 1940. On moist mud, Butler St. cliff of Whitewater gorge at Richmond, *402a*, July, 1941.

Nostoc commune B.&F.—Under overhanging rock at Tufa Falls, *49*, Aug. 10, 1940.

**Nostoc microscopicum* B.&F.—Under overhanging rock at Tufa Falls, *Markle & King 7*, Oct., 1939. On sandy soil in pasture between two R.R. tunnels northwest of Crosley plant, Richmond, *57*, Aug. 18, 1940. On concrete wall of tunnel, Pennsylvania R.R. yards (near Morton Lake) east of Richmond, *75*, Aug. 29, 1940. This specimen is partially lichenized. With *Calothrix parietina* in peelings taken from the south rock ledge above Thistlethwaite's Falls, *160*, Oct. 20, 1940.

**Nostoc ellipsosporum* B.&F.—On moist sand of bank of Whitewater River about 1,000 feet down from Thistlethwaite's Falls—forming wine-red patches on sand, *52*, *53*, Aug. 15, 1940. With *Scytonema Hoffmanii* on moist sandy soil in pasture between two R.R. tunnels northwest of Crosley plant, Richmond, *67*, Aug. 8, 1940.

**Nostoc humifusum* B.&F.—Extensive growths on the clay-shale under the shade of spreading *Rhus aromatica*, Butler Street cliff, Whitewater gorge at Richmond, *232*, Sept. 18, 1940.

**Nostoc spongiiforme* B.&F.—On moist sand of bank of Whitewater River about 1,000 feet down from Thistlethwaite's Falls, *104*, July, 1940.

Cylindrospermum majus B.&F.—With *Nostoc Muscorum* on moist soil in swamp, Friedline farm north of Richmond, *10*, *99*, July 7, 1940. At edge of stream on sandy soil in pasture between two R.R. tunnels northwest of Crosley plant at Richmond, *58*, Aug. 18, 1940. On soil near drainage ditch south of pumping station in Elliott's Mills bog, *114*, July 4, 1940. On moist swamp soil just south of Lake Wehi, *Markle & King 759*, Sept. 7, 1942.

**Cylindrospermum licheniforme* B.&F.—On moist soil of foot path in greenhouse at Centerville, *5a*, April, 1940. On open soil east end of Elliott's Mills bog, *9*, *113*, July 4, 1940. Under ledge at Tufa Falls, *38*, Aug. 14, 1940. On moist soil of recently exposed swamp bed north of Williamsburg, *69*, *380*, Aug. 20, 1940.

**Cylindrospermum muscicola* B.&F.—On exposed soil bank of sewage stream near back pasture at Earlham College, *1*, Sept. 9, 1939. On moist sand edge of Whitewater River below Thistlethwaite's Falls, *36*, *41*, Aug. 14, 1940. On moist sand river's edge below Thistlethwaite's Falls, *117*, July, 1940. On reddish soil near pumping station; and on soil around crayfish excavation—in Elliott's Mills bog, *109*; *110*, July 4, 1940.

On moist sand by river below Thistlethwaite's Falls, *124*, July 27, 1940. With *Dichotomosiphon tuberosus* under falls at Elkhorn, *218*, Sept. 8, 1940.

**Cylindrospermum catenatum* B.&F.—In small depression of soil, east end near pumping station at Elliott's Mills bog, *112*, July 4, 1940.

Rivulariaceae

Calothrix parietina B.&F.—With *Scytonema figuratum* at edge of spray pond, *26*, Aug. 13, 1940. With *Schizothrix lardacea* in shallow water at edge of spray pond, *27*, Aug. 13, 1940. With *Lyngbya purpurea* in shallow water at spray pond, *28*, Aug. 13, 1940. With *Nostoc microscopicum* in peelings taken from rock surface of north ledge above Thistlethwaite's Falls, *160*, Oct. 26, 1940. With *Schizothrix lardacea* in reddish films on shale in north "corner" of Thistlethwaite's Falls, *161*, Aug. 1940. With *S. lardacea* on wet rocks; and in scrapings from rocks—all at Elkhorn Falls, *205*; *205a*, Sept. 7, 1940. With *Schizothrix calcicola* on rock near water at Elkhorn Falls, *216*, Sept. 7, 1940. From surface growth on pipe; and in scrapings from concrete post—all at spray pond, *301*; *374*, Nov. 10, 1940.

**Hassallia byssoidea* B.&F.—Under south rock ledge near old thorn tree, below Thistlethwaite's Falls, *175*, Sept. 5, 1940. New genus for Indiana.

**Scytonema alatum* B.&F.—At Tufa Falls south of Elliott's Mills bog, *Markle & King 7*, Oct., 1939.

Scytonema figuratum B.&F.—With *Calothrix parietina* at edge of spray pond, *26*, Aug. 13, 1940. Growing in compact masses some 3 mm. thick on concrete at edge of spray pond, *29*, Aug. 13, 1940. On edge of rock shelf at Tufa Falls, *130*, 1940. Forming blackish film on rock and on mosses under ledge at Tufa Falls, *Markle & King 762*, Sept. 7, 1942.

**Scytonema Hoffmanii* B.&F.—Film on moist soil (and on rock) under ledge at Tufa Falls, *48*, Aug. 10, 1940. With *Nostoc ellipsosporum* on moist sandy soil in pasture between two R.R. tunnels northwest of Crosley plant at Richmond, *67*, Aug. 18, 1940.

**Scytonema ocellatum* B.&F.—In dense mat on cement wall of coal bin in greenhouse at Centerville, *4*, March, 1940. Small scattered tufts on cracked mud of ditch in woods across from Lewis Woods near Williamsburg, *157*, Aug., 1940. On sandy soil among grass of stream bank near Springwood, *158*, Aug., 1940. On dry clay soil near top of bank of Whitewater gorge near Mt. Auburn, *190*, Sept., 1940. On moist clay-shale near Tufa Falls, *Markle & King*, *764*, Sept. 7, 1942.

**Scytonema crustaceum* B.&F.—Forming brown, felty masses on moist soil of swamp area south of Lake Wehi, *Markle & King*, *752*, Sept. 7, 1942.

Oscillatoriaceae

**Schizothrix purpurascens* Gom.—With *Microcoleus vaginatus* on wet limestone ledges by road just north of Richmond Baking Co., *267*, Sept. 27, 1940. New genus for Indiana.

**Schizothrix Friesii* Gom.—With *Lyngbya aestuarii* on moist sand wedged at base of grass plant at edge of Whitewater River near Mt. Auburn, *21*, Aug. 5, 1940.

**Schizothrix lacustris* Gom.—Extensive reddish-orange growths on vertical faces of moist rock, Whitewater gorge behind Garr-Scott Bldgs., *430*, July 28, 1941.

**Schizothrix lardacea* Gom.—With *Calothrix parietina* in shallow water at edge of spray pond; forming little calcareous mounds at edge of spray pond, *27*; *32*, Aug. 13, 1940. With *Chroococcus rufescens* in moist gravel at edge of spray pond, *30*, Aug. 13, 1940. Covering moist rock of north bluff at Thistlethwaite's Falls, *40*, Aug. 14, 1940. In calcareous material in crevices of stonework, inside wall of R.R. tunnel ½ mile north of Richmond (near Union Pike), *64*, Aug. 18, 1940. With *Calothrix parietina* forming reddish films on shale in north "corner" of Thistlethwaite's Falls, *161*, Aug., 1940. With *Calothrix parietina* on wet rocks at Elkhorn Falls, *205*, Sept. 7, 1940.

**Schizothrix calcicola* Gom.—In incrustations from spray pond, *356a*, *356b*, Nov. 10, 1940. In calcareous material in crevices of stonework inside wall of railroad tunnel ½ mile north of Richmond (near Union Pike), *118*, July 19, 1940. With *Calothrix parietina* on rock by edge of water at Elkhorn Falls, *216*, Sept. 8, 1940.

**Schizothrix fuscescens* Gom.—With *Anacystis Peniocystis* and *Chroococcus turgidus* on wall of cave at Elkhorn Falls, *201*, Sept. 7, 1940. With *Anacystis rupestris* in crevices of cliff at Elkhorn Falls, *203*, Sept. 7, 1940.

**Schizothrix lateritia* Gom.—In calcareous material in crevices of stonework inside wall of R.R. tunnel ½ mile north of Richmond (near Union Pike), *59*, Aug. 18, 1940.

**Microcoleus acutissimus* Gardn.—Dry eroded soil of steep bank of Whitewater River near bridge at Mt. Auburn, *200*, Sept, 7, 1940.

**Microcoleus lacustris* Gom.—With *Microcoleus vaginatus* on moist cracked mud first cliff below Thistlethwaite's Falls. Bright green and noticeable at some distance, *18*, Aug. 5, 1940. With *Lyngbya aestuarii* on mud near Whitewater River, *22*, Aug. 5, 1940.

**Microcoleus vaginatus* Gom.—With *Symploca Muscorum* on mud accumulated in opening of drainage pipe under Nolands Fork Bridge on Greens Fork Pike, *5*, June, 1940. With *Microcoleus lacustris* on moist cracked mud first cliff down river from Thistlethwaite's Falls, *18*, *19*, Aug. 5, 1940. With *Phormidium autumnale* on moist edge of spray pond, *31*, *33*, Aug. 13, 1940. Peelings from horizontal rock and soil surface of

moist ledge by river at Middleborough, *359*, Dec. 23, 1940. With *Anacystis rupestris* on moist soil of swamp just south of Lake Wehi, *Markle & King 738*, Sept, 7, 1942.

**Plectonema roseolum* Gom.—With *Anacystis rupestris* and *Oscillatoria granulata* in laboratory culture at Earlham College, *Markle 4*, 1939.

**Plectonema Nostocorum* Gom.—Beneath dried *Chara* in receded pond area at School St. gravel pit, *46*, Aug., 1940. With *Pleurocapsa varia* in calcareous material in crevices of stonework inside wall of R.R. tunnel ½ mile north of Richmond (near Union Pike), *62*, Aug. 18, 1940. In slime of *Euglena* growths on moist sand at edge of Whitewater River below Thistlethwaite's Falls, *71*, Aug. 22, 1940. With *Oscillatoria tenuis* var. *tergestina* and *Lyngbya aestuarii* in sediment from pool of spray pond, *356*, Nov. 10, 1940. In undersurface masses on floating cat-tail stump in Lake Wehi, *Markle & King 763*, Sept. 7, 1942.

**Plectonema purpureum* Gom.—Mt. Auburn cliff face, Whitewater gorge, *193*, Sept, 17, 1940. On rock shelf at Elkhorn Falls, *214*, Sept. 8, 1940.

**Symploca elegans* Gom.—Very extensive growths on sand, mud, and twigs at edge of stream (water slightly thermal due to waste from Crosley plant) in Crosley woods, north of Richmond, *16*, July 30, 1940.

Symploca Muscorum Gom.—With *Microcoleus vaginatus* on mud accumulated in opening of drainage pipe under Nolands Fork bridge on the Greens Fork Pike, *5*, June, 1940. Twining up the stems of grasses and mosses in the swamp on Friedline farm near Springwood, *6*, July 7, 1940. On tufa formation at Tufa Falls, *47*, Aug. 10, 1940. In a clump of moss on stone by Whitewater River below Thistlethwaite's Falls, *63*, Aug. 15, 1940. On moist rocks on bank of Whitewater River back of Starr Piano Co., *79*, Sept. 2, 1940.

Lyngbya aestuarii Gom.—In quarry pond at Middleborough, *Markle 10*, 1939. On moist cracked mud of dried-up puddle, School Street gravel pit, *15*, July 30, 1940. With *Schizothrix Friesii* on moist sand, edge of Whitewater River, *21*, Aug. 5, 1940. With *Microcoleus lacustris* on mud near Whitewater River, *22*, Aug. 5, 1940. With *O. tenuis* var. *tergestina* and *Plectonema Nostocorum* in sediment from pool at spray pond, *356*, Nov. 10, 1940. On mud near Whitewater Boulevard at Richmond, *119*, Aug., 1940. With *Phormidium autumnale* on moist soil by Whitewater River at Richmond, *400a*, July, 1941. Floating in Lake Wehi, *Markle & King*, *740*, Sept. 7, 1942.

Lyngbya Diguetii Gom.—On submerged stick from Elliott's Mills bog, *8*, June, 1940. Scraped from rocks under spring near Ratliff home by Thistlethwaite's Falls, *37*, Aug. 14, 1940.

**Lyngbya purpurea* Gom.—With *Calothrix parietina* in shallow water of spray pond, *28*, Aug. 13, 1940. From extensive growths on iron pipes at spray pond, *301*, *352*, Nov. 10, 1940. Scraped from rocks at

spring near Ratliff home, *401a*, July, 1941. Little tufts attached to bottom in shallow water, edge of Lake Wehi, *756*; with *Chroococcus rufescens* floating in Lake Wehi, *753*, *754*; bright orange tufts attached to floating cat-tail stump in Lake Wehi, *758*—all by *Markle & King* Sept. 7, 1942.

Phormidium tenue Gom.—In bottom of shallow stream between R.R. tunnels ½ mile north of Richmond (near Union Pike), *68*, Aug. 18, 1940. With *Oscillatoria tenuis* and *O. princeps* in floating masses at edge of Lake Wehi, *Markle & King 742*, Sept. 7, 1942.

Phormidium Retzii Gom.—At Tufa Falls southeast of Richmond, *133*, Aug. 1940.

**Phormidium subfuscum* var. *Joannianum* Gom.—Extensive and thick mats on sluice gate at dam of Whitewater River at Richmond, *25*, Aug. 9, 1940. On moist rocks near stream outlet back of Starr Piano Co., *80*, Sept. 2, 1940. In drainage ditch of spray pond, *422*, *429*, July 28, 1941.

Phormidium uncinatum Gom.—On rock in shallow water at sewer outlet near G. St. bridge, Sept. 27, 1940. On moist soil near sewage outlet and pumping station in back pasture at Earlham, *144*, July, 1940. Extensive growths on falls at Middleborough, *362*, Dec. 23, 1940. From a number of observations made in December this species seemed to be the dominant alga growing at this time of the year on the falls at Middleborough and also on the rocks at Thistlethwaite's Falls.

Phormidium autumnale Gom.—In standing water in small limestone depression below Thistlethwaite's Falls, *20*, Aug. 5, 1940. With *Microcoleus vaginatus* at edge of spray pond, *33*, Aug. 13, 1940. On low damp ground back of pump house back of Earlham, *129*, July, 1940. On damp soil along Whitewater Blvd. near R.R. bridge, *106*, Aug., 1940. With *Lyngbya aestuarii* on moist soil by Whitewater River at Richmond, *400a*, July, 1941.

Phormidium incrustatum Gom.—On dry calcareous shale by sewer outlet just north of G. St. bridge, *166*, Sept. 2, 1940. Growing on tufa at edge of large formation at Tufa Falls, *Markle & King 761*, Sept. 7, 1942.

Phormidium minnesotense (Tild.) Drouet—With *Oscillatoria formosa* on muddy Whitewater River bank behind Starr Piano Co., *81*, Sept. 2, 1940. With *O. tenuis* at Whitewater River at Richmond, *433*, July 28, 1941. Reported by Drouet (5) for Wayne County.

**Oscillatoria granulata* Gardn.—In laboratory culture at Earlham College, *Markle 4*, 1939.

Oscillatoria princeps Gom.—With *Oscillatoria limosa* and *Chroococcus turgidus* in floating masses in pool of spray pond, *50*, Aug. 15, 1940. Very extensive floating masses behind dam of Whitewater River at Richmond, *24*, *55*, Aug. 9 & 15, 1940. With *O. limosa* in floating masses in pool of spray pond, *72*, Aug., 1940. In about 2 in. of water in Whitewater River at base of cliffs near Bridge Ave., *367*, Sept. 24, 1940. With

Phormidium tenue and *O. tenuis* in floating masses at edge of Lake Wehi; with *O. tenuis* in small hatchery pond just south of Lake Wehi—both *Markle & King 742* and *765*, Sept. 7, 1942.

Oscillatoria proboscidea Gom.—On moist sandy soil on bank of Whitewater River behind Starr Piano Co., *78*, Sept. 2, 1940.

Oscillatoria limosa Gom.—With *O. princeps* and *Chroococcus turgidus* in floating masses in pool of spray pond; with *O. princeps* in floating masses in same pool, *50*, *72*, Aug. 15, 1940.

Oscillatoria tenuis Gom.—On soil by old ditch back of Starr Piano Co., *168*, Sept. 2, 1940. With *Phormidium minnesotense* at Whitewater River near Natco bldgs. at Richmond, *433*, July 28, 1941. With *O. splendida* floating in Lake Wehi, *736*, *749*; with *P. tenue* and *O. princeps* in Lake Wehi, *742*; with *O. princeps* in small hatchery pond just south of Lake Wehi, *765*—all *Markle & King*, Sept. 7, 1942.

**Oscillatoria tenuis* var. *natans* Gom.—In shallow inlet of water by Whitewater River near Mt. Auburn at Richmond, *23*, Aug. 9, 1940. Floating in pool below Thistlethwaite's Falls, *92*, July 7, 1940.

**Oscillatoria tenuis* var. *tergestina* Gom.—With *Plectonema Nostocorum* and *Lyngbya aestuarii* in sediment from bottom of pool of spray pond, *356*, Nov. 10, 1940. In floating masses in pool of spray pond, *426*, July 28, 1941.

Oscillatoria splendida Gom.—In floating material from pool of spray pond, *375*, Nov. 10, 1940. With *O. tenuis* floating in Lake Wehi, *Markle & King 736*, *749*, Sept. 7, 1942.

Oscillatoria formosa Gom.—With *Phormidium minnesotense* on mud bank of Whitewater River behind Starr Piano Co., *81*, Sept. 2, 1940. On rocks in shallow water at edge of Whitewater River below Main St. bridge, *82*, Sept. 2, 1940.

Spirulina major Gom.—On moist soil in Elliott's Mills bog, *7*, July 4, 1940.

Acknowledgments

The writer wishes to express his gratitude to Dr. Francis Drouet for the determinations of the material included in this paper, and for generous advice and criticism; to William A. Daily for the identification of certain specimens; to Dr. M. S. Markle, of Earlham College, for encouraging the writer's interest in the algae as well as making possible some of the material included here; and to Dr. C. M. Palmer for aid in the preparation of this work.

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Cuscuta obtusiflora H.B.K. var. *glandulosa* Engelm. in Indiana

T. G. Yuncker, DePauw University

On August 14, 1925, C. C. Deam collected a specimen of dodder (No. 41990) growing on *Dianthera americana* L. in the Tippecanoe River about 1 mile below Monticello in White County. This specimen was subsequently sent to me for identification. It did not, however, agree with any of the then known Indiana species and was placed aside for further study. It was overlooked for a number of years and only recently has been restudied.

In a critical examination of the plant it is now evident that it is in reality *Cuscuta obtusiflora* H.B.K. var. *glandulosa* Engelmann (*C. glandulosa* (Engelm.) Small), and, as such, represents the first known report of this variety for Indiana.

C. obtusiflora is widely distributed through South America. The variety *glandulosa*, however, does not occur, so far as I know, in South America but exhibits a more northern distribution through the West Indies from Trinidad to Cuba, where it has been collected a number of times. It also occurs in the southern United States from Florida and Georgia to Texas, where it appears to be most abundant. It has also been collected in southern California and in central Mexico. The northernmost collections previously known were made in Oklahoma and central Arkansas. Its occurrence in northern Indiana, therefore, represents an unusual and remarkable extension of the range for this variety.

The flowers are commonly 5-parted, glandular, subsessile in scattered, moderately open, glomerulate-cymose clusters. The calyx lobes are ovate, obtuse, scarcely overlapping at the base and with one lobe generally distinctly smaller than the others. The corolla tube is campanulate, with ovate to ovate-oblong, obtuse or acutish, upright to spreading lobes. The infrastamineal scales are oblong, fringed with medium length processes about the top, sometimes bifid or truncated. The styles are stoutish and subulate and shorter than the depressed-globose capsule which has a widely gaping interstylar aperture.

It prefers marsh or semi-aquatic hosts particularly species of *Polygonum* and often is erroneously identified as *C. Polygonorum* Engelmann. The flowers of *C. Polygonorum*, however, are mostly 4-parted, with triangular, acute corolla lobes, and mostly bifid and somewhat reduced infrastamineal scales. The only other Indiana species with which it might be confused is *C. Campestris* Yuncker. The calyx lobes of that species are more or less overlapping at the base and the corolla lobes are triangular to sublanceolate and acute. The styles are mostly slender, the interstylar aperture smaller, and the infrastamineal scales larger and more abundantly fringed.

How the seeds of this variety reached northern Indiana is an interesting question. One possibility is that they were carried from some southern station by migrating water fowl, presumably adhering to the feet or legs in a bit of mud.

Pollen Profile from Sediments of an Extinct Lake in Hendricks County, Indiana Marks Time of Drainage*

J. E. Potzger, Butler University

On the farm of Mr. H. D. Barlow, three miles northwest of Plainfield, Hendricks County, Indiana, is a magnificant empty bowl of an extinct lake whose wall rises abruptly forty feet or more above the floor. Two large cuts in the eastern embankment give mute evidence of the draining of this lake into the much lower-placed White Lick Creek. The southeastern part of the extinct lake was a mucky area when Mr. Barlow took possession of the farm, and peat formed a fairly deep deposit. It at once became apparent to the writer that pollen deposits in this peaty layer would not only bear record of forest succession in Hendricks County following retreat of Early Wisconsin glacination but also mark the approximate time when the lake was drained. So a boring was made in the peat, which totaled eight feet at the maximum.

Thanks is expressed to Mr. Harold Gibbs, who drew the writer's attention to the old lake basin; to Mr. H. D. Barlow, owner of the farm, for his readily granted permission to have the boring made on his property; to my colleagues, C. Mervin Palmer and Ray C. Friesner, also to Mr. C. O. Keller, graduate student in our department, for assistance rendered in the boring work.

Physiographic History of the Region

The region dates origin of its topographic features to Early Wisconsin glaciation and subsequent carving by running water, primarily that of White Lick creek and its larger and smaller tributaries, which in some places have made substantial cuts through the unconsolidated glacial drift, resulting in steep flanking slopes, and dissected topography in general. The glacial drift is at times very deep. Mr. M. F. Gibbs reports that in a well boring on his farm logs were struck at a depth of 85 feet.

The Characteristics of the Ancient Lake

The outline of the old basin perhaps is as definite now as it was in days when water filled the depression, except that two cuts through the eastern wall today mark the head of an intermittent stream to White Lick creek which is placed at least 25 feet lower than the lake bottom. This elevated position of the lake no doubt aided greatly in the breakdown of the rather narrow eastern retaining wall, giving rise to a small creek which gradually cut below the original bottom of the lake. The more substantial flanking walls are even today preserved excellently, enclosing an area of perhaps 80 acres. Large granitic boulders are strewn conspicuously over uplands and the floor of the bowl. Among the unusual features left as evidence of the scouring and grinding action

* This is contribution 141 from the botany laboratories of Butler University, Indianapolis, Indiana.

of the vanished ice masses is one large granite block ground into a flat base and rising cap-like above the surface soil.

Methods

Boring was made with the movable-sleeve type borer described in many of our previous papers dealing with pollen studies of bogs. Small samples of peat were secured at each foot-level, placed into a bottle, and marked with foot-level and location. The stoppers were sealed with paraffin to retain moisture in the peat sample. Moist samples yield readily separated material. In the preparation of slides the Geisler (2) method was followed. This eliminates the rough treatment with KOH and acids as suggested by a number of workers for the preparation of slides, and prevents excessive breakage of pollen from conifers. 200 grains of pollen of trees were counted at each foot-level except at the pollen-deficient lowest level, where only 75 grains were counted.

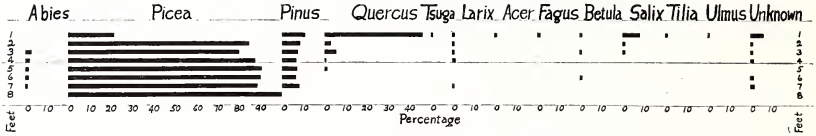

TABLE I.—Pollen Percentages Representing Various Genera in a Pollen Profile from Peat of an Extinct Lake in Hendricks County, Indiana

Foot Level	Abies	Picea	Pinus	Quercus	Tsuga	Larix	Acer	Fagus	Betula	Salix	Tilia	Ulmus	Unknown
1	....	21½	11	46	½	1	1	1½	1	8	1	½	6
2	....	84½	8½	3	....	1	.. ..	....	.. ..	1	....	....	1
3	3½	80	7½	5½	....	1	.. ..	....	½	1	....	....	1
4	2	87½	6½	½	....	1½	....	....	....	....	....	....	1½
5	1½	90½	7	1	....	....	....	....	....	....	....	....	....
6	1½	90	6½	....	....	....	....	....	½	....	....	....	1½
7	1	88½	8	....	....	½	....	....	....	....	....	....	2
8	....	100	....	....	....	....	....	....	....	....	....	....	....

Results

Table 1 and figure 1 present in summary the story of forest succession up to the time of drainage of the ancient lake. The first tree cover consisted entirely of Picea; scattered and open forest are indicated by the somewhat sparse representation of pollen in the sediment. Abies was not abundant at any time, and passed out at the 3-foot level. While Pinus was never very important, it increased towards the topmost level. The boreal forest yielded suddenly to the deciduous forest complex, with Quercus as most important genus. No pronounced Pinus period is indicated. This lack of Pinus is a characteristic feature of pollen profiles from bogs located in Early Wisconsin territory in Indiana. In Hendricks county Quercus advanced from insignificant representation at the 5- and 4-foot levels to co-dominance with Picea and Pinus in the surface layer, indicating a moderating climate. This change of climate is further to be

inferred from the invasion of a number of our typical mesophytic climax genera, such as Fagus, Acer, Tilia and Ulmus. At this stage the record ends, marking the closing chapter and drainage of the ancient lake. Apparently the small creeks had now cut deeply enough into the loose material of the narrow retaining wall along the eastern border to accomplish the drainage of the lake to White Lick creek. This took place rather early in Post-Pleistocene times, coinciding with the decline of the boreal forest, in fact, it might have occurred during the Picea period and pollen of the broadleaved genera might have accumulated in the pool-like southwest area after the major part of the lake had been drained.

Discussion

Peat deposits are not common in the region of southernmost extension of Early Wisconsin glaciation. The most typical well-developed bog along the border is perhaps Bacons Swamp in Indianapolis, where peat has accumulated to a depth of 32 feet. While the story of forest succession in the Hendricks county peat is only fragmentary, it involves at least the whole Picea period and reaches into that pronounced change to moderating climate which enabled the deciduous genera to compete with and replace the coniferous forests in Indiana (fig. 1, table 1). If we compare the truncated profile from Hendricks county with the complete ones reported by Otto (3), Prettyman (4) and Barnett (1) for bogs in different areas of Indiana which were affected by Early Wisconsin glaciation we find that only about one-third to one-half of the forest history had been recorded in the Hendricks county peat.

The large number of foot-levels recording control by Picea in Hendricks county is characteristic of regions where silt and clay constitute the soil adjacent to the lake. In lakes and bogs flanked by sandy soil, and in which boring is limited to the organic sediments, the number of foot-levels recording forest made up chiefly of Picea is much reduced In such lakes early sediments consist primarily of fine sand in which the pollen of pioneer forests is embedded.

The ancient lake in Hendricks county existed as a body of water only a comparatively short time, perhaps only a few thousand years. When its waters ebbed away to the nearby White Lick Creek recording ceased, and the magnificent empty bowl with high, steep walls has continued as an extinct lake since that day, while countless centuries rolled on unmarked, as spruce and pine declined, and eventually disappeared entirely when the last of these genera yielded to the pressure of the climatically favored southern deciduous forest.

Summary

1. The paper presents a pollen profile of a shallow peat deposit in an extinct lake in Hendricks county, Indiana.

2. The old lake basin is excellently preserved, but a cut through the eastern wall drained the waters to White Lick Creek before deep lake and peat sediments could accumulate.

3. The small deeper southwest section of the old bowl had an 8-foot deep layer of peat.

Picea to the period when broadleaved genera, primarily Quercus, began to crowd out the conifers. From a complete dominance (100%) at the 8-foot level, Picea declined to 21½% at the top-most level, while Quercus is here represented with 46%.

5. At this period, or perhaps earlier, the old lake must have been drained, and records closed. Drainage thus occurred at the very beginning of the characteristic long oak period, which in Indiana is represented by the upper two-thirds of the total sediment.

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Pollen Study of Sediments from Douglas Lake, Cheboygan County and Middle Fish Lake, Montmorency County, Michigan

Ira T. Wilson, Heidelberg College, Tiffin, Ohio, and J. E. Potzger, Butler University[1]

The two lakes occupy a somewhat central position in the upper part of the lower peninsula of Michigan. Douglas Lake has been made famous by the Biological Station of the University of Michigan located on its shores. It is perhaps one of the most extensively studied lakes in North America. It is about 15 miles south of the Straits of Mackinac. Middle Fish Lake, one of a group of three lakes in Montmorency County, is 45 miles south and 28 miles east of Douglas Lake. At both locations the original forest consisted of pine and northern hardwoods in disjunct distribution, determined by the nature of the soil. Pine occupied primarily sandy areas and hardwoods the better loam and clay soils. When civilized man first settled in these counties the boreal forest (spruce, fir, tamarack) was reduced to relic colonies in bogs and along wet river valleys. For a detailed description of these remnants of northern forests in the Douglas Lake region we refer to Gates (1942). The original distribution of these various forest cover types in the Douglas Lake area is shown by Gates (1926) in an excellent map of the region. Agriculture was limited to soils originally covered by northern hardwoods, and it was always a poorly rewarded enterprise. During the early days of pioneer settlements, the farmer depended primarily upon lumbering for an adequate income.

The samples analyzed for this study represent only a part of a series of cores taken at both lakes to study configuration of the lake bottom and the nature of the sediments.

Characteristics of the Lakes and Fringing Vegetation

Douglas Lake was and still is of great depth and considerable surface area. Wave action has prevented formation of a bog mat along the periphery except in beach pools and in protected bays and coves (Gates, 1942). Both pine and northern hardwoods stands flanked the shores, their location being determined by the soil (Gates, 1926). Lowlands and depressions along streams supported forests controlled by Thuja, Larix, Picea and Abies (Gates, 1926, 1942; Gates and Ehlers, 1924). "Boring 4" was made in the deepest part of what is known as East Fish Tail Bay (depth of water 69 feet). This bay receives considerable protection against prevailing winds from Grapevine Point. The original basin had a depth of 125 feet. From the 102- to the 110-foot levels the sediments consisted of hard-packed reddish clay which embodied considerable sand at the 103-foot level. Abundant organic matter first

[1] This is contribution 142 from the Botanical Laboratories of Butler University.

appeared at the 101-foot level. No samples were taken from the 104- to the 109-foot levels.

The Fish lakes occupy depressions in the main moraine of the Port Huron morainic system. Sandy drift is abundant in the neighborhood of these lakes.

Middle Fish Lake is rapidly nearing extinction, 93.76 percent of the basin is filled. The greater part of the original water surface is occupied by a bog mat, leaving only a shallow central pond (depth of water five feet) of 2.49 acres. The deepest boring (No. 1) penetrated to a depth of 56 feet. From the 43-foot level downward the sediment consisted of comparatively coarse sand (size of particles similar to those along the shore), in which small fragments of wood and very few pollen grains (only two pollen grains to ten slides) were embedded. No representative pollen count was attempted for these levels. Very fine sand constituted the sediments from the 43- to the 38-foot levels (Fig. 1) in which pollen became very abundant at the 38-foot level.

Residents of the region about Fish Lake described the forest as having been pine and hardwoods, but principally pine. While *Pinus banksiana*, *P. strobus* and *P. resinosa* were represented in the forest complex, *P. strobus* was most abundant. Among the broad-leaved species mentioned were *Acer saccharum*, *A. rubrum* and *Quercus velutina*. Specific mention was made of the infrequent occurrence of Tsuga. Along the edge of the lake the typical bog species (Thuja, Picea, Larix, Abies) constituted the fringing forest.

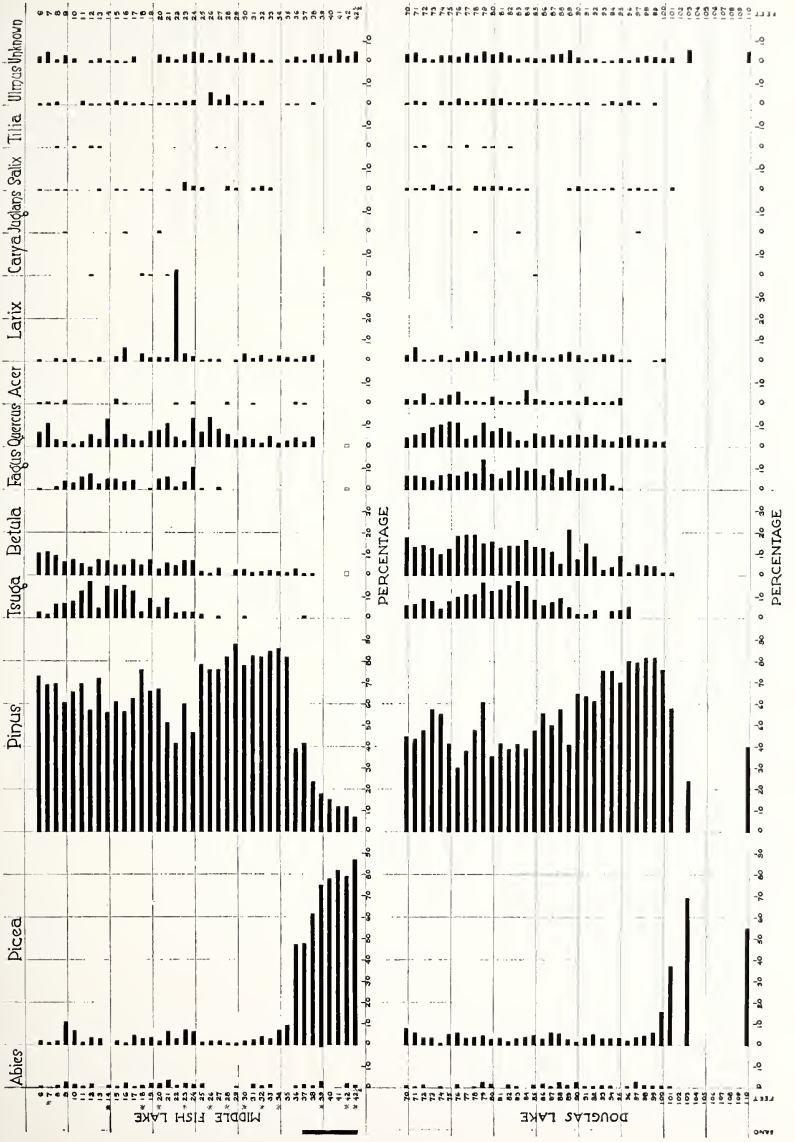
Methods

Collecting of samples was carried out with the Wilson sampler. This instrument was described by Wilson (1941) and in the pollen study of Minnesota lakes by Wilson and Potzger (1942). The Geisler (1935) method was followed in the preparation of the slides. At Douglas Lake 200 pollen grains of tree genera were counted for each foot-level except in the lower part where pollen was poorly represented. A count of 200 grains bgan at the 101-foot level. At Middle Fish Lake counts of 100 and 200 were alternated except when critical changes in the forest cover was in evidence. The difference in percentage representation between a count of 100 and 200 pollen grains was so small that practically nothing was contributed to the story by the additional count of 100 grains, especially when forest cover type was more or less the same for a long period. Levels represented by 100 pollen grains are starred in Figure 1. Pollen of shrubby and herbaceous genera was tabulated but they have been omitted from the figure because their small representation apparently added nothing of significance as far as vegetational succession was concerned. One per cent aqueous solution of gentian violet was used for staining.[2]

Results

Both profiles begin with a decided spruce period, but pine was represented from the very beginning. It was especially prominent in the lowest level of Douglas Lake (Fig. 1). At both stations the spruce period was succeeded by a spruce-pine association which yielded abruptly to a

decided pine dominance, and this was later depressed by the invading broad-leaved genera associated with hemlock to less than 50 per cent representation in the pollen spectrum. At this stage importance of certain genera differed somewhat at the two stations. At Douglas Lake pine seldom exceeded 50 per cent of total tree pollen after its depression



[2] We express our thanks to Miss Jane Goodlet for the lettering on figure 1.

at the 89-foot level. At middle Fish Lake pine recovered much of its pre-depression importance and retained this to the topmost level. The broad-leaved complex consisted primarily of Fagus, Betula and Quercus with Tsuga as associate. Abundance of these various genera fluctuated at different levels, while pine maintained a striking uniform representation. Tsuga decreased appreciably towards the topmost levels at both stations. This may perhaps be interpreted as a result of less favorable moisture conditions. Broad-leaved genera never attained the importance at Middle Fish Lake which they held at Douglas Lake. If the percentages of pollen of Quercus, Betula, Fagus, Acer and Tsuga are totaled the difference in importance of the hardwoods at the two locations is accentuated. At Douglas Lake these genera constitute from one-third to one-half of the total pollen after depression of the pine period (92- to 70-foot levels), while at Middle Fish Lake their representation for the northern hardwoods period (24- to 6-foot levels) fluctuated between one-fifth and one-third of the total pollen count.

An unusual temporary abundance of Larix is shown at the 22-foot level in Middle Fish Lake, which was not approximated again after that period.

Discussion

In the early forest succession there is little difference between the Michigan stations and those of Wisconsin (Potzger, 1942; Potzger and Richards, 1942), Minnesota (Wilson and Potzger, 1942), New Jersey (Potzger and Otto, 1942). At all these places Pinus was associated with Picea from the beginning stages of forest invasion. This differs, however, from early succession in Indiana and the southern part of lower Michigan (Otto, 1938; Potzger and Wilson, 1941) where the initial forest consisted entirely of Picea and Abies. Retardation of a decided control by Quercus, on the other hand, resembles the behavior of the genus at stations in northern Michigan and Wisconsin (Potzger, 1942; Potzger and Richards, 1942). Decline of Pinus with the invasion of deciduous genera associated with Tsuga resembles greatly the succession in the Gillen Nature Reserve (Potzger, 1942) except that Fagus is absent in the complex of the deciduous forest in that part of Wisconsin.

Acer, again, presents a problem for the interpretation of the constitution of the deciduous forest because its low pollen representation does not reflect the true importance of this genus in the forest cover. This was pointed out by Potzger (1942) for the forests about the bogs in the Gillen Nature Reserve. It also fails to reflect the true importance of this genus in the hardwoods complex represented by the two Michigan stations, as one of us knows from the acquaintance with the forest in Presque Isle and Montmorency counties; and as Gleason (1924), Potzger (1941), Gates (1926, 1942) show in field studies from these northern counties. Gates (1924) describes *Acer saccharum* as "one of the most abundant trees of the region." It is also interesting how the brief statements in the annotated list by Gates and Ehlers (1924) correlate with representation of the same genera in the pollen spectrum. Tilia, "not very abundant." Ulmus, "a few old trees in wetter parts of beech-maple

woods." *Betula lutea*, "most abundant in the beech-maple woods." *Quercus velutina*, "infrequent in the jack pine plains."

The incorrect representation of Acer in the spectrum may introduce the possibility of a two-fold distortion of the interpretation of a pollen profile, viz. the underestimation of importance of Acer and overestimation of importance of Pinus. If Acer constituted the major part of the broad-leaved forest its absence in the pollen record would give pine a too prominent place; it will certainly give the impression that Betula and Fagus as well as Tsuga had greater representation in the northern hardwoods than they really did have. However, pine occupied a prominent place in the forest cover of Montmorency county, and the hardwoods was scattered in disjunct areas, so the distortion in the pollen spectrum may not be so great even though Acer is not represented in proportion to its actual abundance in the forest. The general description of the forest cover given by the residents at the Montmorency county station also supports the pollen record showing greater importance of Pinus at Middle Fish Lake than at Douglas Lake.

Both of the lakes are in a latitude where Quercus has not exerted much control in the crown cover. It evidently approximates here the status of this genus in the forests of Wisconsin (Potzger, 1942). Its early appearance in the profiles show that it is not a matter of retarded invasion but rather a depression by some climatic factor which does not influence such genera as Betula, Fagus and Acer. What was said of the lake forest of northern Wisconsin and upper Michigan (Potzger, 1942) apparently also applies to the forests represented by the two stations. The northern hardwoods appears to be the climatically favored type, and pine maintains itself primarily by aid of edaphic factors which limit the more aggressive broad-leaved genera in their invasion of sandy habitats. This interpretation also echoes the opinion voiced by Gates (1926).

Summary

1. The paper presents pollen profiles from sediments of Middle Fish Lake, Montmorency County, and Douglas Lake, Cheboygan County, Michigan. Both of the lakes are located in the upper third of the lower peninsula of Michigan.

2. In a general way both profiles show the same succession types, which was from Picea to Picea-Pinus to Pinus to Pinus-deciduous forest.

3. Tsuga was associated with the deciduous genera Fagus, Betula, Acer.

4. The invasion by deciduous species depressed the importance of Pinus to less than 50 per cent of the total pollen. At Middle Fish Lake it recovered some of the lost abundance but at Douglas Lake the Tsuga-deciduous complex maintained its controlling influence.

5. The deciduous forest was never so important at the Middle Fish Lake station as at Douglas Lake.

6. Tsuga is to all appearances a component of the northern hardwoods and not of the Pinus element in the lake forest.

7. Tsuga declined in abundance during the time in which the five topmost levels of sediment at both lakes were laid down.

8. The opinion is expressed that the deciduous forest here as in northern Wisconsin is the climatically favored phase of the lake forest, and that pine occupies the position of relic favored by soil factors.

Acknowledgment

We gratefully acknowledge that a grant from the Institute of Fisheries Research of the Department of Conservation of Michigan supported most of the field work at both lakes; and that additional financial aid was given the work at Douglas Lake by the Michigan Academy of Science and the University of Michigan Biological Station.

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Preparation of 2 x 2 Inch Slides or 35 mm. Filmstrips by a Rapid and Inexpensive Method

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Visual education has firmly entrenched itself among modern pedagogical methods. The added interest which it evokes, the ease with which the unknown is made familiar, the clarity achieved comparable only with that of actual experience, and the simplicity of presentation of complex data make it invaluable. This method would be much more widely used were it not for the expense and time involved and the lack of storage space for sets of illustrations for daily lectures. Since the advent of 35 mm. film, these problems are much more easily solved. In addition, the projector for these small slides is less bulky and more easily handled and transported from place to place. There are a number of inexpensive projectors on the market suitable for this purpose.

The following is an inexpensive method whereby slides or film strips can be made in one series of operations with the expenditure of relatively little time and money. The time spent in first making a negative and then printing a posittive is eliminated, since the positives are made directly. There are several films manufactured specifically for this purpose on the market, such as Eastman's Panchromatic Positive film, but they are very expensive to use. The method described here is the one which Eastman advocates for its Panchromatic Positive film, but the length of time in certain of the steps in processing is changed so that it is applicable to Eastman Kodak Safety Positive film, which is extremely inexpensive in comparison with the cost of the former.

The various steps in the process together with the necessary formulas follows:

1. Develop for 8 minutes with agitation in a film tank at 68° F. The solution used here is Kodak D-67, which consists of:

Water (50° C.)	500 cc.
Elon	2.2 grams
Sodium Sulfite, desiccated	96.0 grams
Hydroquinone	8.8 grams
Sodium Carbonate, monohydrated	56.1 grams
Potassium Bromide	5.0 grams
Sodium Thiocyanate	2.0 grams
Water to make	1.0 liter

2. Rinse in water for 30 seconds. It is advisable after the use of each of the following solutions up to the sixth step to rinse in water for 30 seconds.

3. Harden for 5 minutes (10 min. above 75° F.): Kodak SB-4

Water	1.0 liter
Potassium Chrome Alum	30.0 grams
Sodium Sulfate, desiccated	60.0 grams

4. Bleach for 3 minutes: Kodak R-9

Water	1.0 liter
Potassium Bichromate	9.4 grams
Sulfuric Acid, C. P.	12.0 cc.

5. Clear for 2 minutes: Kodak CB-1

Water	1.0 liter
Sodium Sulfite, desiccated	90.0 grams

6. Redevelop with a chemical fogging developer for 5 minutes at 68° F.: Kodak FD-68

Water (50° C.)	500.0 cc.
Elon	2.2 grams
Sodium Sulfite, desiccated	96.0 grams
Hydroquinone	8.8 grams
Sodium Carbonate, monohydrated	56.1 grams
Sodium Hydroxide	10.0 grams
Hydrazine Sulfate	1.0 grams
Water to make	1.0 liter

7. Use short stop bath for one minute: SB-1

Water	1.0 liter
Acetic Acid (28%)	48.0 cc.

8. Fix in any film fixing bath for twice the time to clear. When fresh, Eastman's F-6 used for 5 minutes is very satisfactory.

9. Wash in water for 20 minutes.

10. Wipe off excess water with photographic sponge and dry.

For each two degrees of increase in temperature the time of development should be decreased by one minute and vice versa. It is preferable, however, to develop at 68° F. The other baths need not be kept at this temperature but should all be kept constant at any given temperature. Preferably this temperature should be between 65-75° F. The redeveloper is very susceptible to oxidation and should be protected from it. The quality of the final positive, assuming correct exposure, depends largely upon the time and temperature used in the first development. Should any backing remain on the film after processing, place the film in a 5% solution of desiccated sodium sulphite and then rewash. As in Kodachrome, overexposure or overdevelopment results in the positive being too light, while underdevelopment or underexposure causes the transparency to be too dark. For purposes of projection, as with any lantern slide, it is preferable to have the transparency on the light side rather than to have it too dark.

All processes can be carried on in the darkroom under a Wratten Series OA safelight. It may be desirable to follow through the entire process with the aid of the safelight until the technique has become familiar. If one purchases a daylight developing tank the whole process from start to finish can be carried out in the light.

The use of the Eastman Kodak Safety Positive Film for a purpose not intended by the manufacturer necessarily requires the recognition of certain limitations and the observation of certain precautions if one is to be successful.

First of all, the film is not a panchromatic one and therefore is not color sensitive. As a result the film can be used only for copying printed matter, black and white line drawings and half tones.

Second, the latitude of the film is very narrow since with the reverse processing there is little chance to compensate for over- or underexposure. Consequently the exposure, as for Kodachrome, must be nearly correct to give good results.

Third, the manufacturers' film ratings can not be used in calculating exposure to photofloods. Safety Positive Film is very sensitive to the blue light in photofloods and when they are used as the light source the film is faster. With two No. 2 photofloods in reflectors that cast 150 foot candles on the material to be copied and with the camera ten inches away an exposure of 1/25 of a second with the diaphragm set halfway between the stops f11 and f8 is about right. This would indicate a film rating of 12 on a General Electric exposure meter. For dark pictures or ones with dark backgrounds f8 is best. While not necessary, yet for speed and convenience in the actual copying, a constant focusing device that at the same time delineates the field is very helpful. The one described by Alyea[1] was found to be excellent and although originally designed for a Leica it can be easily modified to fit an Eastman Kodak 35, a Perfex, or an Argus.

The expense involved in this method is slight as compared with that of the usual method of first making a negative and then a positive, since the cost of the film for the negative is eliminated. One cartridge of Eastman's Panchromatic Direct Positive Film, containing 36 exposures, costs $1.35 and is not available in bulk, whereas a hundred-foot roll of Safety positive film used in this method costs about $2.00 and contains enough films for 18 rolls each of which has 36 exposures. This makes the film cost of the individual slide negligible.

There are several types of slide binders on the market. The ones put out by the Society for Visual Education called SVE slide binders that cost $3.25 per hundred have been found to be excellent. These can be rapidly and easily used and have space on which may be written pertinent information about the slide. Using these, the cost complete of a 2 x 2 inch slide is less than four cents as compared with a partial cost of at least eight cents for the large 3¼ x 4 inch slide, which does not count the cost of the binding tape or the original negative.

Lastly, there is the time factor. By the use of this method, slides can be made in an hour from the time the picture is copied to the finished transparency, including a 20-minute washing period. The biggest difference between this method and the one described by Milne[2] is that the latter uses an eclectic assortment of photographic formulas, some of which are made up immediately before use and are then discarded, while the method here described uses solutions all of which may be reutilized.

Facility in the use of this method can be obtained relatively easily and will well repay one for the time spent in perfecting his technique.

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Additions to the Hepaticae of Indiana II

Dorothy Parker, University of Cincinnati

From an examination of 131 packages of liverworts the following list of thirty new county records was made. Of these, two species are reported for the first time and one of these belongs to a genus (*Jubula*) previously unreported for the state.

The writer wishes to thank Dr. Winona Welch and Mr. Donald Richards for their specimens, and Dr. Margaret Fulford, who checked the identification of some doubtful forms.

The species list is arranged in the following manner: the species name is followed by the county in which it was collected, the county name is followed by a symbol which indicates the Herbarium in which the specimen is deposited and the number following the symbol indicates the owners number of the packet. The symbols used are: W—the Herbarium of Winona H. Welch, R—the Herbarium of Donald Richards, and P—the Herbarium of the writer. The asterisk (*) denotes the new state records.

Lophocolea heterophylla (Schrad.) Dum. Crawford Co. (W) 6773; Dubois Co. (W) 6767; Jefferson Co. (W) 6791, 6793, 6795, 6800; Randolph Co. (P) 610; Shelby Co. (P) 605; Wells Co. (P) 617.

Diplophyllum apiculatum (Evans) Steph. Putnam Co. (W) 6857.

Porella platyphylloidea (Schwein.) Lindb. Crawford Co. (W) 6775; Fayette Co. (P) 602, 604; Jennings Co. (W) 6758; Shelby Co. (P) 606, 607; Randolph Co. (P) 613, 616; Wells Co. (P) 618, 619.

Frullania eboracensis Gottsche. Crawford Co. (W) 6774, 6829; Fayette Co. (P) 601, 639; Jennings Co. (W) 6760; Owen Co. (W) 6863, 6868, 6896; Perry Co. (W) 6766; Randolph Co. (P) 611, 614, 615; Shelby Co. (P) 607; Wells Co. (P) 618.

**Frullania Brittoniae* Evans. Jennings Co. (W) 6754, 6755, 6756; Jefferson Co. (W) 6803; Shelby Co. (P) 608, 609.

**Jubula pennsylvanica* (Steph.) Evans. Parke Co. (W) 6746; Putnam Co. (W) 6847, 6877.

Cololejeunea Biddlecomiae (Aust.) Evans. Randolph Co. (P) 612.

Pallavicinia Lyellii (Hook.) Gray. Porter Co. (R) 27.

Conocephalum conicum (L.) Dum. Dubois Co. (W) 6769; Posey Co. (W) 6763.

Indiana Plant Distribution Records, III. 1942

This is a continuation of the series of reports of new distribution records intended to keep Deam's "Flora of Indiana" up to date. Beginning with this report three sections will be maintained, viz: "SPECIES," giving new county records with location of confirming specimens; "NOMENCLATORIAL CHANGES" in which an attempt will be made, within the limits and in the spirit of conservative taxonomy, to keep the "Flora" up to date in plant names as well as plant distribution, and "DELETIONS" in which known previous errors will be corrected.

Species

Genera are listed in the same order as that used in the "Flora" and species are given in alphabetical order in their respective genera. Symbols following the counties indicate herbaria where specimens have been deposited. Species, varieties or forms new for the state are given in bold face type and these, together with new segregations or other taxonomic changes, are followed by literature references. Species concerning which there may be some doubt as to whether they will be able to establish themselves and become a part of the state flora, are preceded by an asterisk.

The specimens here listed have been collected by the following collectors: Butler University (B): Charles M. Ek, W. C. Clifton, Charles C. Deam, Arian Evans, Ray C. Friesner, Scott McCoy, and John E. Potzger; Deam Herbarium (D): Charles C. Deam and Charles M. Ek; DePauw University (DP): Charles C. Deam and T. G. Yuncker; Franklin College (Fr.): Naomi Mullendore; Huntington College (Hu): Fred Loew; Indiana University (IU): Carol Groves, Jean Hartman, Edwin D. Hull, Joe Lipps, Dorothy Sanders, Paul Weatherwax and Helen M. Zeiner; University of Notre Dame (ND): Charles C. Deam; Purdue University (P): A. T. Guard; Wabash College (W): A. R. Bechtel and W. C. Leavenworth.

Other symbols used are: (E) Earlham College; (F) Field Museum; (G) Gray Herbarium; (H) Frederick Hermann, Private Herbarium; (I) University of Illinois; (MC) Scott McCoy, Private Herbarium; (N) U. S. National Herbarium; (NW) Northwestern University; (NY) New York Botanical Garden; (T) R. M. Tryon, Jr., Private Herbarium; (Wi) University of Wisconsin.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species recorded in the "Flora" or subsequently added in these reports by requesting same from the secretary of this committee.

Ophioglossum vulgatum, Jennings (B). *Botrychium virginianum*, Hendricks (B), Shelby (B). *Osmunda claytoniana*, Jefferson (B). *Cystopteris fragilis* var. *protrusa*, Hamilton (B), Hendricks (B), Shelby

(B). *Asplenium platyneuron*, Shelby (B). *Equisetum arvense*, Boone (B), Clinton (B), La Porte (B), Shelby (B). *E. laevigatum*, Boone (B), Clinton (B), Elkhart (B), Hamilton (B), Hendricks (B), Howard (B), Lagrange (B), Madison (B), Miami (B), Tipton (B). *E. praealtum*, Clinton (B), Tipton (B). *Lycopodium lucidulum*, Morgan (IU).

Potamogeton amplifolius, Howard (B). *Alisma subcordatum*, Hamilton (B), Shelby (B), Vanderburgh (IU). *Triglochin maritima*, Kosciusko (B).

Bromus commutatus, Hendricks (B), Jackson (B), Jennings (B). *B. inermis*, Tippecanoe (B). *B. japonicus*, Marion (B). *B. purgans*, Bartholomew (B), Hendricks (B), Shelby (B). *B. secalinus*, Carroll (B), Hancock (B), Hendricks (B), Jackson (B). *Festuca elatior*, Clinton (B). *F. obtusa*, Hancock (B), Hendricks (B). *F. rubra*, Jennings (B). *Glyceria grandis*, Howard (B). *G. septentrionalis*, Huntington (Hu), Cass (B). *G. striata*, Jennings (B). *Poa annua*, Elkhart (B), Jennings (B), Vanderburgh (IU). *P. chapmaniana*, Jackson (B). *P. compressa*, Clinton (B), Elkhart (B), Hancock (B), Hendricks (B). *P. pratensis*, Hancock (B), Jennings (B). *P. sylvestris*, Hendricks (B). *P. wolfii*, Montgomery (B).

Eragrostis cilianensis, Boone (B), Clinton (B), Madison (B), Shelby (B). *E. frankii*, Hendricks (B), Madison (B), Pulaski (B), Shelby (B). *E. hypnoides*, Shelby (B). *E. pectinacea*, Boone (B), Shelby (B). *Diarrhena americana*, Hendricks (B), Tipton (B). *Dactylis glomerata*, Hancock (B), Hendricks (B), Jackson (B), Jennings (B). *Triodia flava*, Elkhart (B), Hamilton (B), Marion (B), Shelby (B), Tipton (B). *Agropyron repens*, Carroll (B), Hamilton (B). *A. smithii*, Hamilton (B). **Aegilops cylindrica*, Tippecanoe (B). *Elymus canadensis*, Boone (B), Elkhart (B), Hamilton (B), Hendricks (B), Madison (B). *E. riparius*, Elkhart (B), Hendricks (B). *E. villosus*, Boone (B), Hendricks (B), Marion (B), Shelby (B). *E. virginicus*, Boone (B), Elkhart (B), Hancock (B), Hendricks (B), Huntington (Hu), Shelby (B.) *E. v.* var. *glabriflorus*, Shelby (B). *E. v.* var. *jejunus*, Elkhart (B).

Sphenopholis intermedia, Hendricks (B), *S. nitida*, Hendricks (B). *S. obtusata*, Greene (IU), Montgomery (W). *Danthonia spicata*, Hendricks (B). *Calamagrostis inexpansa*, Steuben (B). *Agrostis alba*, Tipton (B). *A. perennans*, Hamilton (B). *A. scabra*, Cass (B), Hamilton (B), Howard (B), Jasper (B), Lagrange (B), Pulaski (B). *Cinna arundinacea*, Fountain (W), Huntington (Hu). *Alopecurus carolinianus*, Montgomery (W). *Phleum pratense*, Madison (B). *Muhlenbergia foliosa*, Hamilton (B), Tipton (B). *M. mexicana*, Owen (IU). *M. schreberi*, Boone (B), Huntington (Hu). *Sporobolus asper*, Huntington (Hu), Montgomery (W). *S. cryptandrus*, Elkhart (B). *S. neglectus*, Madison (B). *Brachyelytrum erectum*, Hamilton (B), Hendricks (B). *Aristida oligantha*, Marion (B), Tipton (B). *Leptochloa panicoides*, Lawrence (IU), Orange (IU). *Eleusine indica*, Boone (B), Hamilton (B), Hendricks (B), Shelby (B).

Phalaris arundinacea, Montgomery (W). *Leersia oryzoides*, Hendricks (B), Madison (B). *L. virginica*, Boone (B), Hendricks (B), Madison (B), Tipton (B). *Digitaria ischaemum*, Boone (B), Madison (B), Marion (B), *D. sanguinalis*, Boone (B), Hamilton (B), Madison (B). *Leptoloma cognatum*, Hamilton (B). *Paspalum pubescens*, Hendricks (B), Tippecanoe (P). *Panicum ashei*, Jennings (B). *P. bicknellii*, Bartholomew (B). *P. capillare*, Shelby (B). *P. clandestinum*, Fulton (B), Hendricks (B). *P. dichotomiflorum*, Clinton (B), Elkhart (B), Tipton (B). *P. gattingeri*, Hamilton (B), Madison (B). *P. huachucae*, Huntington (Hu). *P. latifolium*, Hendricks (B). *P. meridionale*, Steuben (B). *P. scribnerianum*, Hamilton (B), Jackson (B). *P. virgatum*, Elkhart (B), Hamilton (B). *Echinochloa crusgalli*, Elkhart (B), Hamilton (B). *Setaria italica*, Boone (B). *S. lutescens*, Boone (B), Elkhart (B), Shelby (B). *S. verticillata*, Marion (B). *S. viridis*, Boone (B), Hancock (B), Shelby (B). *Cenchrus pauciflorus*, Boone (B), Brown (B), Carroll (B), Elkhart (B), Hendricks (B), Shelby (B), Tipton (B), Vanderburgh (IU). *Andropogon furcatus*, Shelby (B). *A. scoparius*, Johnson (Fr). *Sorghum halpense*, Vanderburgh (IU).

Cyperus densicaespitosus Mattf. & Kukenth. Pflanzenr. 20:597. 1936 (*Kyllingia pumila*), Shelby (B). *C. strigosus*, Hamilton (B), Hendricks (B), Shelby (B), Tipton (B). *Scirpus acutus*, Miami (B). *S. americanus*, Hendricks (B). *S. atrovirens*, Boone (B). *S. lineatus*, Clinton (B), Tipton (B). *Eleocharis obtusa*, Tippecanoe (B). *E. tenuis* var. *verrucosa*, Boone (B), Cass (B). *Carex brevior*, Starke (D), Wabash (B). *C. buxbaumii*, Kosciusko (B). *C. conjuncta*, Grant (B). *C. emoryi*, Howard (B). *C. frankii*, Carroll (B), Elkhart (B).

Carex inflata var. *utriculata* (C. *rostrata*, Rhodora 44:324), Steuben (B). *C. hyalinolepis*, Tipton (B). *C. intumescens*, DeKalb (B). *C. i.* var. *fernaldii f.* **ventricosa** Fern., cited in Rhodora 44:321-322. 1942 without county designation. *C. lacustris*, Elkhart (B), Miami (B). *C. laxiflora*, Elkhart (B). *C. leptalea*, Elkhart (B). *C. lurida*, Steuben (B). *C. molesta*, Tippecanoe (B). *C. muskingumensis*, Carroll (B), Marion (B). *C. normalis*, Kosciusko (B), Wabash (B). *C. pennsylvanica*, Pulaski (D). *C. plantaginea*, Owen (IU). *C. scoparia*, Cass (B). *C. sparganioides*, Brown (B), Hamilton (B). *C. subimpressa*, Montgomery (W). *C. substricta*, Elkhart (B). *C. viridula*, Elkhart (B). *C. v.* f. *intermedia*, Elkhart (B).

Symplocarpus foetidus, Owen (IU). *Arisaema atrorubens*, Hendricks (B). *A. a.* f. *virde*, Jefferson (B). *A. a.* f. *zebrina*, Hendricks (B), Jackson (B), Jennings (B). *Commelina communis*, Howard (B), Tippecanoe (B). *Juncus brachycarpus*, Pulaski (B). *J. dudleyi*, Marion (B). *J. gerardi*, Miami (B). *J. macer*, Grant (B). *J. torreyi*, Marion (B), Tippecanoe (B), Tipton (B). *Tofieldia glutinosa*, Kosciusko (B). *Melanthium virginicum*, Miami (B). *Uvularia grandiflora*, Hendricks (B). *Hemerocallis fulva*, Vanderburgh (IU). *Allium canadense*, Miami (B). *A. cernuum*, Hamilton (B), Marion (B). *A. sativum*, Elkhart (B). *A. tricoccum*, Hamilton (B). *Nothoscordum bivalve*, Perry (IU). *Lilium michi-*

ganense, Huntington (Hu), Johnson (Fr). *Camassia scilliodes*, Martin (IU). *Asparagus officinalis*, Clinton (B), Elkhart (B). *Smilacina racemosa*, Shelby (B). *Polygonatum canaliculatum*, Hamilton (B). *P. pubescens*, Hendricks (B). *Trillium gleasoni*, Hendricks (B). *T. nivale*, Huntington (Hu). *T. recurvatum*, Hendricks (B). *T. r.* f. *luteum*, Hendricks (B). *Dioscorea villosa*, Hamilton (B). *Iris cristata*, Jennings (B). *I. virginica* var. *shrevei*, Vanderburgh (IU). *Sisyrinchium albidum*, Greene (IU). *Triphora trianthophora* var. **schaffneri** Camp, Rhodora 42:55. 1940, Parke (B), (D), (NY), Henry (NY), Hamilton (NY). *Spiranthes gracilis*, Newton (B). *Corallorrhiza wisteriana*, Bartholomew (Fr).

Saururus cernuus, Carroll (B), Johnson (Fr.). *Populus deltoides*, Shelby (B). *Salix cordata*, Tipton (B). *S. interior*, Clinton (B). Hendricks (B), Shelby (B), Tipton (B). *S. nigra*, Howard (B). *Juglans nigra*, Boone (B). *Carya laciniosa*, Boone (B), Hamilton (B), Shelby (B). *C. ovalis*, Hamilton (B). *C. ovata*, Boone (B). *Carpinus caroliniana* var. *virginiana*, Shelby (B). *Ostrya virginiana* f. *glandulosa*, Hamilton (B). *Corylus americana*, Huntington (Hu). *Betula nigra*, Johnson (Fr). *Fagus grandifolia*, Boone (B), Shelby (B). *Quercus alba*, Boone (B), *Q. bicolor*, Clinton (B). *Q.* **borealis** Ashe, Collected by C. C. Deam. See Flora, p. 380, Allen (D), Wells (B), (D), (DP, (ND). *Q. b.* var. *maxima*, Boone (B), Hamilton (B), Hendricks (B), Shelby (B). *Q. ellipsoidalis*, Elkhart (D). *Q. falcata*, Vanderburgh (IU). *Q. imbricaria*, Elkhart (B), Hamilton (B). *Q. macrocarpa*, Boone (B), Shelby (B). *Q. muhlenbergii*, Madison (B), Shelby (B).

Ulmus americana, Boone (B), Shelby (B). *U. fulva*, Boone (B), Shelby (B). *Celtis occidentalis* var. *crassifolia*, Boone (B), Carroll (B), Shelby (B). *Morus rubra*, Madison (B). *Humulus americana*, Elkhart (B). *Urtica procera*, Shelby (B). *Laportea canadensis*, Carroll (B). *Pilea pumila*, Shelby (B), Tipton (B). *Parietaria pennsylvanica*, Boone (B), Hendricks (B), Shelby (B), Tipton (B). *Commandra richardsiana*, Huntington (Hu). *Asarum reflexum*, Hendricks (B). *Aristolochia serpentaria*, Bartholomew (B), Hendricks (B), Knox (B), (MC), Marion (B), (MC), Shelby (B). *Rumex acetosella*, Hancock (B). *R. altissima*, Tippecanoe (B). *R. crispus*, Cass (B), Carroll (B), Hancock (B). *Polygonum aviculare*, Elkhart (B). *P. buxiforme*, Boone (B), Carroll (B), Elkhart (B), Lagrange (B), Shelby (B), Tipton (B). *P, convolvulus*, Hendricks (B), Marion (B). *P. dumetorum*, Elkhart (B). *P. erectum*, Carroll (B). *P. hydropiper* var. *projectum*, Boone (B), Hamilton (B), Madison (B). *P. hydropiperoides*, Madison (B). *P. lapathifolium*, Elkhart (B), Hamilton (B). *P. neglectum*, Boone (B), Carroll (B), Clinton (B), Hamilton (B), Madison (B), Miami (B), Shelby (B). *P. pennsylvanicum* var. *laevigatum*, Jasper (B), Madison (B), Shelby (B), Starke (B), Tipton (B). *P. p.* var. *l.* f. *pallescens*, Carroll (B), Hamilton (B), Shelby (B). *P. persicaria*, Boone (B), Elkhart (B), Hamilton (B), Hendricks (B). *P. punctatum*, Shelby (B). *P. scandens*, Shelby (B), Tipton (B). *P. virginianum*, Clinton (B), Shelby (B). *Fagopyrum esculentum*, Howard (B).

Chenopodium ambrosioides ssp. *euambrosioides*, Clinton (B), Tipton (B). *C. a.* ssp. *eua.* var. *anthelminthicum*, Elkhart (B). *C. berlandieri* ssp. *Zschackei*, *Clinton* (B), Howard (B), Whitley (B). *C. botrys*, Tipton (B). *C. gigantospermum*, Elkhart (B), Howard (B). *C. praterícola*, Clinton (B). *C. standleyanum*, Elkhart (B). *Atriplex patula* var. *hastata*, Tipton (B). *A. p.* var. *littoralis*, Clinton (B). *Cycloloma atriplicifolium*, Tipton (B). *Coriospermum hyssopifolium*, Elkhart (B). *Salsola pestifer*, Elkhart (B), Tipton (B). *Amaranthus blitoides*, Cass (B), Clinton (B). *A. hybridus*, Cass (B), Clinton (B), Tipton (B). *A. retroflexus*, Elkhart (B). *A. spinosus*, Wells (D). *Acnida altissima*, Cass (B), Shelby (B), Tipton (B). *Froelichia gracilis*, Elkhart (B), La Porte (B). *Oxybaphus nyctagineus*, Hamilton (B), Hendricks (B). *Phytolacca americana*, Hendricks (B). *Mollugo verticillata*, Cass (B), Hamilton (B). *Claytonia virginica*, Hamilton (B).

Stelaria aquatica*, Hendricks (B). *S. pubera*, Hendricks (B). *Cerastium arvense*, Howard (B). *C. vulgatum* var. *hirsutum*, Elkhart (B). *C. v.* var. *h.* f. *glandulosum*, Jackson (B). *Paronychia fastigiata* var. *typica*, Shelby (B). *Holosteum umbellatum*, Montgomery (W). *Agrostemma githago*, Hendricks (B), Jackson (B). *Silene antirrhina*, Clinton (B), Hendricks (B). *S. cserei*, Elkhart (B). *S. cucubalus*, Hendricks (B). *S. stellata* Hendricks (B). *Lychnis alba*, Johnson (Fr), Miami (B), Porter (B). *Saponaria officinalis*, Boone (B). *Nuphar advena*, Huntington (Hu). *Delphinium ajacis*, Miami (B). *Anemone canadensis*, Clinton (B). *A. quinquefolia* var. *interior*, Howard (B). *A. virginiana*, Hamilton (B). *Clematis viorna*, Johnson (Fr). *C. virginiana*, Hamilton (B), Tipton (B). *Ranunculus abortivus* var. *typicus*, Clark (D), Fountain (Wi), Hendricks (B), Lawrence (Wi). *R. a.* var. **acrolasius Fern. Rhodora 40:18. 1938. See Amer. Midland Nat. 27:512. 1942. Fountain (Wi). *R. recurvatus*, Jennings (B), (D). *R. repens* var. *villosus*, Cass (B). *T. revolutum*, Elkhart (B).

Podophyllum peltatum, Hendricks (B). *Menispermum canadense*, Hendricks (B). *Asimina triloba*, Hamilton (B), Madison (B). *Sassafras albidum*, Clinton (B). *Lindera benzoin*, Shelby (B). *Corydalis flavula*, Martin (IU). *Lepidium campestre*, Elkhart (B). *L. densiflorum*, Hendricks (B). *L. virginicum*, Boone (B), Clinton (B), Jackson (B), Jennings (B). *Sisymbrium altissimum*, Carroll (B), Clinton (B), Elkhart (B), Hendricks (B). *S. officinale*, Cass (B), Howard (B), Miami (B). *S. o.* var. *leiocarpum*, Hendricks (B), Jennings (B), Tipton (B). *S. thalianum*, Monroe (IU). **Erucastrum gallicum*, Howard (B), Grant (B). *Brassica juncea*, Cass (B), Elkhart (B), Howard (B). *B. nigra*, Boone (B), Carroll (B), Cass (B), Shelby (B), Tippecanoe (B), Tipton (B). *Rorippa islandica* var. *microcarpa*, Clinton (B), Hamilton (B), Shelby (B). *R. sessiliflora*, Monroe (IU). *Armoracea rusticana*, Elkhart (B). *Camelina microcarpa*, Marion (B). *Draba verna*, Elkhart (B), Marion (B), Vanderburgh (IU). *Decurainia pinnata* var. *brachycarpa*, Jackson (B). *Arabis laevigata*, Clinton (B), Elkhart (B). *Conringia orientalis*, Marion (B).

Polanisia graveolens, Brown (B), Cass (B), Clinton (B), Elkhart (B). *Drosera intermedia*, Hamilton (B). *Penthorum sedoides*, Hendricks (B), Hamilton (B), Huntington (Hu), Tipton (B). *Saxifraga pennsylvanica* ssp. *eupennsylvanica* Burns. Amer. Midland Nat. 28:142-147. 1942. Cass (B), Clark (N), Fountain (B), Hamilton (B), Howard (B), Lagrange (B), Lake (I), Marion (B), Marshall (N), Monroe (B), Montgomery (B), Porter (B), Wells (D), (N), White (B). *S. p.* ssp. *interior* var. **crassicarpa** (Johnson) Burns. loc. cit. Cass (B), Jasper (I), Lake (I), (Wi), Porter (I), Starke (B). *S. p.* ssp. i. var. *c.* f. **bracteata** Burns. loc. cit. Porter (Wi). *S. p.* ssp. i. var **winnebagoensis** (Johnson) Burns loc. cit. Lake (NW). *Mitella diphylla*, Hendricks (B). *Platanus occidentalis*, Shelby (B).

Spiraea alba, Hamilton (B), *Malus coronaria*, Howard (B). *Crataegus crusgalli*, Cass (B), Elkhart (B). *C. mollis*, Cass (B), Howard (B). *C. pedicellata*, Howard (B). *C. punctata*, Elkhart (B). *Rubus hispidus*, Huntington (Hu). *R. occidentalis* f. *pallidus*, Crawford (B), Putnam (DP). *Fragaria virginiana*, Elkhart (B). *Potentilla recta*, Clinton (B), Crawford (B). *P. simplex* var. *typica*, Jennings (B). *Geum canadense*, Hancock (B). *G. lacinatum* var. *trichocarpum*, Marion (B). *Agrimonia pubescens*, Miami (B), Tipton (B). *A. rostellata*, Hamilton (B). *Rosa carolina*, Vanderburgh (IU). **R. gallica*, Howard (B). *R. palustris*, Madison (B), Vanderburgh (IU). *R. rubiginosa*, Huntington (Hu). *R. setigera* var. *tomentosa*, Madison (B). *Prunus hortulana*, Hendricks (B). *P. mahaleb*, Wabash (B). *P. nigra*, Huntington (Hu). *P. serotina*, Wabash (B).

Cassia fasciculata, Porter (B). *C. marilandica*, Huntington (Hu). *Gleditsia triacanthos*, Cass (B), Hamilton (B), Madison (B). *Gymnocladus dioica*, Carrol (B). *Medicago lupulina*, Bartholomew (B), Hamilton (B), Hendricks (B), Miami (B), Vanderburgh (IU). *M. sativa*, Hamilton (B), Miami (B), Tippecanoe (B). *Melilotus alba*, Hendricks (B), Tipton (B). *M. officinalis*, Carroll (B), Cass (B), Hendricks (B), Tipton (B). *Trifolium pratense*, Boone (B), Carroll (B), Miami (B). *T. repens*, Hendricks (B). *Psoralea tenuiflora*, Tippecanoe (B). *Robinia pseudoacacia*, Carroll (B), Hendricks (B). *R. viscosa*, Porter (IU). *Glycyrrhiza lepidota*, Miami (B). *Desmodium canescens*, Hamilton (B). *D. dillenii*, Boone (B), Hamilton (B). *D. glutinosum* (Muhl.) Wood (*D. acuminatum*), Elkhart (B), Hamilton (B), Tipton (B). *D. paniculatum*, Miami (B). *D. rotundifolium*, Elkhart (B). *Lespedeza capitata* var. *stenophylla* Bissell & Fernald. Rhodora 43:579. 1941. (*L. c.* var. *longifolia*), Jasper (G), Porter (G), White (G). *L. c.* var. *velutina*, Jasper (B), Porter (B). *L. c.* var. **vulgaris** T. & G. Rhodora 43:577. 1941. Lake (G). *Clitoria mariana*, Monroe (IU). *Amphicarpa bracteata*, Hamilton (B), Tipton (B). *A. b.* var. *comosa*, Hamilton (B). *Vicia villosa*, Brown (B).

Geranium carolinianum var. *confertiflorum*, Cass (B), Jennings (B), (D), Perry (B). *G. maculatum*, Jennings (B), (D). *G. robertianum*, Elkhart (B). *Oxalis europaea*, Boone (B), Carroll (B), Elkhart (B),

Hendricks (B). *O. e.* var. *bushii* f. *subglabrata*, Howard (B). *O. e.* var. *b.* f. *vestita*, Marion (B), Miami (B). *O. e.* f. *villicaulis*, Carroll (B), Clinton (B), Elkhart (B), Hamilton (B), Hancock (B), Howard (B), Tippecanoe (B), Tipton (B). *O. stricta*, Cass (B), Hendricks (B), Jennings (B). *O. violacea* var. *trichocarpa*, Clay (Wi), Franklin (Wi), Castanea 7:37. 1942. *Zanthoxylum americanum*, Hamilton (B). *Ptelea trifoliata*, Elkhart (B). *Polygala paucifolia* f. **alba** Wheelock. Mem. Torr. Bot. Cl. 2:142. 1891. Porter (D).

Croton monanthogynus, Hamilton (B), Hendricks (B). *Acalypha rhomboidea*, Shelby (B). *Euphorbia corollata*, Hamilton (B), Huntington (Hu). *E. cyparissias*, Elkhart (B), Miami (B). *E. dentata*, Clinton (B), Elkhart (B), Hendricks (B), Huntington (Hu), Jasper (B). *E.* **geyeri** Engelm. Rhodora 44:407. 1942. Lake (F), (G), (IU). *E. maculata*, Hamilton (B), Shelby (B). *E. marginata*, Elkhart (B). *E. peplus*, St. Joseph (ND). *E. supina*, Boone (B), Carroll (B), Miami (B), Shelby (B). *E. vermiculata*, La Porte (B). *Floerkea proserpinacoides*, Monroe (IU). *Rhus radicans* f. **negundo** (Greene) Fern. Rhodora 43:594. 1941. Madison (G). *Ilex verticillata*, Huntington (Hu). *Celastrus scandens*, Hamilton (B). *Acer negundo*, Shelby (B). *Acer nigrum* f. *pubescens*, Cass (B), De Kalb (B), Kosciusko (B), Miami (B), Warren (B). *A. saccharinum*, Carroll (B), Huntington (Hu), Shelby (B). *A. saccharum*, Boone (B). *Aesculus glabra*, Elkhart (B).

Impatiens biflora, Huntington (Hu). *I. pallida*, Huntington (Hu). *Vitis aestivalis*, Huntington (Hu). *V. palmata*, Vanderburgh (IU). *V. vulpina*, Clinton (B). *Parthenocissus quinquefolia*, Vanderburgh (IU). *Tilia americana*, Boone (B). *Abutilon theophrasti*, Shelby (B), Tipton (B). *Malva neglecta*, Miami (B). *Sida spinosa*, Hamilton (B), Shelby (B). *Hibiscus trionum*, Clinton (B), Elkhart (B), Hendricks (B). *H. militaris*, Huntington (Hu). *H. ascyron*, Miami (B). *H. canadense*, Steuben (B). *H. perforatum*, Clinton (B), Hendricks (B), Johnson (Fr). *Viola eriocarpa*, Vanderburgh (IU). *V. e.* f. *leiocarpa*, Howard (B). *V. missouriensis*, Jennings (B). *Passiflora incarnata*, Knox (IU). *P. lutea* var. *glabrifolia*, Bartholomew (B), Shelby (B), Vanderburgh (IU). *Lythrum alatum*, Marion (B), Ohio (B), Shelby (B). *Decodon verticillatus*, Hamilton (B). *Ludwigia palustris* var. *americana*, Hendricks (B). *Oenothera laciniata*, Crawford (B). *Oe. pycnocarpa*, Boone (B), Hendricks (B), Tipton (B). *Oe speciosa*, Clinton (B). *Circaea quadrisulcata* var. *canadensis*, Clinton (B).

Aralia nudicaulis, Elkhart (B). *A. racemosa*, Fountain (W). *A. spinosa*, Brown (B). *Panax quinquefolium*, Jennings (D). *Sanicula canadensis* var. *typica*, Boone (B), Fulton (B). *S. c.* var. *grandis*, Shelby (B). *S. gregaria*, Hendricks (B), Jennings (B). *Chaerophyllum procumbens*, Elkhart (B). *Conium maculatum*, Tippecanoe (B). *Taenidia integerrima*, Jennings (B). *Sium suave*, Hamilton (B), Madison (B). *Cryptotaenia canadensis*, Elkhart (B), Shelby (B). *Thaspium barbinode*, Boone (B), Elkhart (B). *Oxypolis rigidior*, Elkhart (B), Huntington (B), Madison (B), Tipton (B). *Pastinaca sativa*, Clinton (B), Tippe-

canoe (B), Tipton (B). *Daucus carota*, Hendricks (B), Miami (B). *Cornus racemosa*, Jennings (B). *Epigaea repens*, Elkhart (B). *Samolus parviflorus*, Huntington (Hu), Shelby (B). *Lysimachia ciliata*, Tipton (B). *L. lanceolata*, Miami (B). *L. longifolia*, Johnson (Fr). *L. nummularia*, Huntington (Hu). *L. quadrifolia*, Montgomery (W). *Fraxinus americana*, Boone (B). *F. nigra*, Huntington (Hu). *F. quadrangulata*, Fountain (W), Hamilton (B).

Sabatia angularis, Johnson (Fr). *Obolaria virginica*, Putnam (DP). *Frasera carolinensis*, Huntington (Hu). *Apocynum androsaemifolium*, Huntington (Hu). *A. cannabinum*, Boone (B). *A. c.* var. *glaberrimum*, Boone (B), Hendricks (B), Shelby (B), Tippecanoe (B). *Asclepias incarnata*, Hamilton (B). *A. quadrifolia*, Jennings (B), (D). *A. syriaca*, Boone (B), Clinton (B), Hendricks (B), Tipton (B), Vanderburgh (IU). *A. tuberosa*, Greene (IU). *A. verticillata*, Boone (B), Hendricks (B). *Ampelamus albidus*, Cass (B), Miami (B). *Cuscuta campestris*, Clark (D), (DP). *C. cephalanthi*, Howard (DP). *C.* **obtusiflora** var. **glandulosa** Engelm. Mem. Torr. Bot. Cl. 18:128. 1932. Indiana Acad. Sci. Proc. 52: 1942 (1943). Coll. by C. C. Deam, White (DP), (D). *C. polygonorum*, Putnam (DP), Lawrence (DP). *Convolvulus arvensis*, Hamilton (B), Tippecanoe (B). *C. sepium* var. **americanus** Sims. Indiana Acad. Sci. Proc. 49:90. Kosciusko (D), Lagrange (D), La Porte (D), Steuben (D). *C. s.* var. **communis** Tryon, loc. cit. Allen (D), Lake (D), Marion (B), Ripley (D), Vigo (D), Whitley (D). *C. s.* var. *fraterniflorus*, loc. cit. Adams (D), Allen (D), Floyd (D), Owen (D), Posey (D), Warrick (D), Wells (D). *C. s.* var. *repens* (L.) Gray, loc. cit. Bartholomew (D), Boone (B), Brown (D), Carroll (D), Clay (D), Dearborn (D), Greene (D), Hamilton (D), Hancock (D), Hendricks (D), Montgomery (D), Putnam (D), Shelby (D), Tipton (D), Vermillion (D), Wells (D), White (D). *C. spithamaeus*, Lawrence (D). *C. spithaemaeus* var. *catesbianus* (Pursh) Tryon, loc. cit. Crawford (D), Noble (D), Orange (D), Perry (D), Pike (D). *Ipomoea hederacea*, Shelby (B). *I. pandurata*, Elkhart (B).

Phlox paniculata, Shelby (B). *Polemonium reptans*, Hendricks (B). *Hydrophyllum canadense*, Hendricks (B). *Cynoglossum officinale*, Hancock (B), Miami (B). *Lappula echinata*, Cass (B). *Hackelia virginiana*, Boone (B), Elkhart (B), Hendricks (B), Shelby (B). *Myosotis verna* Nutt. (*M. virginica*) Rhodora 43:636. 1941. Jennings (B). *Lithospermum arvense*, Monroe (IU). *Verbena bracteata*, Cass (B), Miami (B). X *V. engelmannii*, Carroll (B). *V. stricta*, Tipton (B). *V. urticaefolia*, Clinton (B), Hamilton (B), Hancock (B), Hendricks (B), Madison (B). *Phyla lanceolata*, Huntington (Hu), Tipton (B), Wayne (E).

Teucrium canadense var. *virginicum*, Clinton (B), Hendricks (B), Miami (B), Shelby (B), Tipton (B). *T. occidentale* var. *boreale*, Elkhart (B). *Scutellaria galericulata*, Hamilton (B). *S. lateriflora*, Hamilton (B), Hendricks (B). *S. nervosa*, Huntington (Hu). *S. ovata*, Johnson (Fr). *S. parvula*, Howard (B). *Marrubium vulgare*, Cass (B), Elkhart (B). *Agastache nepetoides*, Howard (B). *Prunella vulgaris* var. *lanceolata*, Hamilton (B). *Physostegia virginiana*, Hamilton (B).

Lamium amplexicaule, Elkhart (B). *Stachys palustris* var. *homotrichia*, Clinton (B). *S. riddellii*, Bartholomew (B). *S. tenuifolia*, Carroll (B), Elkhart (B), Shelby (B). *Salvia reflexa*, Howard (B). *Leonurus cardiaca*, Boone (B). *Blephilia hirsuta*, Johnson (Fr). *Hedeoma pulegioides*, Clinton (B), Shelby (B). *Lycopus americanus*, Hendricks (B). *L. rubellus*, Madison (B). *Mentha* **alopecurioides** Hull. Gray Man. 7 ed. p. 710. Coll. by C. M. Ek. Elkhart (B). *M. arvensis*, Hamilton (B), Monroe (IU). **M. longifolia* var. *undulata*, Miami (B), Porter (B). *M. piperita*, Clinton (B). *M. spicata*, Elkhart (B), Hendricks (B).

Nicandra physalodes, Shelby (B). *Lycium halimifolium*, Elkhart (B), Hamilton (B). *Physalis ambigua*, Boone (B). *P. heterophylla*, Hamilton (B), Miami (B). *P. subglabrata*, Elkhart (B), Hamilton (B), Hendricks (B), Madison (B), Shelby (B). *S. virginiana*, Tippecanoe (B). *Solanum carolinense*, Hamilton (B). *S. dulcamara*, Cass (B). *S. nigrum*, Clinton (B), Hendricks (B), Miami (B). *Datura stramonium*, Shelby (B). *Verbascum blattaria*, Clinton (B), Elkhart (B). *V. thapsus*, Boone (B), Hamilton (B). **Linaria* **macedonica** Griseb. Bailey Man. Cult. Plt. p. 675. Coll. by C. M. Ek. Elkhart (B), (D). *Chaenorrhinum minus*, Clinton (B), Hamilton (B). *Collinsia verna*, Brown (IU), Huntington (Hu), Owen (IU). *Scrophularia marilandica*, Boone (B), Elkhart (B), Hendricks (B), Huntington (Hu). *Chelone glavra* var. *linifolia*, Madison (B). *C. g.* var. *l.* f. *velutina*, Porter (B). *Penstemon digitalis*, Howard (B). *Mimulus alatus*, Carroll (B), Hendricks (B), Johnson (Fr), Shelby (B). *Gratiola neglecta*, Boone (B). *Leucospora multifida*, Marion (B), Shelby (B). *Lindernia dubia*, Shelby (B). *Veronica anagallis-aquatica* f. *anagalliformis*, Clinton (B), Shelby (B). *V. arvensis*, Jennings (B). *V. peregrina* var. *xalapensis*, Jennings (B). *Gerardia purpurea*, Hamilton (B). *G. tenuifolia* var. *typica*, Madison (B). *G. t.* var. *macrophylla*, Madison (B). *Aureolaria flava* var. *typica*, Elkhart (B). *Pedicularis lanceolata*, Madison (B).

Campsis radicans, Hamilton (B), Shelby (B), Tipton (B). *Ruellia carolinensis*, Marion (B). *R. strepens*, Clinton (B). *R. s.* f. *cleistantha*, Miami (B). *Dianthera americana*, Clinton (B), Shelby (B). *Plantago aristata*, Carroll (B), Hancock (B). *P. cordata*, Porter (F). **P. indica*, Elkhart (B). *P. lanceolata*, Bartholomew (B), Boone (B), Carroll (B), Hendricks (B). *P. major*, Elkhart (B). *P. rugelii*, Clinton (B), Tipton (B). *P. virginica*, Elkhart (B). *Houstonia purpurea*, Vanderburgh (IU). *Cephalanthus occidentalis*, Carroll (B), Huntington (Hu). *Galium aparine*, Hendricks (B). *G. concinnum*, Shelby (B), Tipton (B). *G. triflorum*, Shelby (B). *Diodia teres* var. *setifolia*, Cass (B), Tipton (B). *Viburnum molle*, Wayne (B), (D). *V. prunifolium*, Boone (B). *Triosteum aurantiacum*, Hamilton (B). *T. a.* var. *illinoense*, Jennings (B). *T. perfoliatum*, Hamilton (B), Huntington (Hu). *Symphoricarpos orbiculatus*, Cass (B). *Lonicera canadensis*, Elkhart (B). *L. japonica*, Vanderburgh (IU). *Valerianella intermedia*, Monroe (IU). *Dipsacus sylvester*, Boone (B), Hamilton (B). **Cucurbita foetidissima*. See Flora p. 1094. Coll. by E. D. Hull. Lake (IU). *Sicyos angulatus*, Cass (B). *Campanula americana*, Boone (B). *Specularia perfoliata*, Vanderburgh (IU). *Lobelia inflata*, Huntington (Hu), Shelby (B).

Vernonia altissima, Madison (B). *Eupatorium altissimum*, Elkhart (B). *E. maculatum*, Madison (B). *E. perfoliatum*, Huntington (Hu). *E. purpureum*, Boone (B), Elkhart (B), Miami (B). *E. rugosum*, Huntington (Hu). *E. serotinum*, Madison (B). *Kuhnia eupatorioides*, Elkhart (B). *Liatris cylindracea*, Elkhart (B). *L. scariosa* f. *benkei*, Jasper (B). *Solidago altissima*, Shelby (B). *S. caesia*, Clinton (B), Huntington (Hu). *S. gigantea* var. *leiophylla*, Hamilton (B). *S. juncea*, Miami (B). *Aster cordifolius*, Tipton (B). *A. ericoides*, Miami (B). *A. macrophyllus*, Vanderburgh (IU). *A. novae-angliae*, Huntington (Hu). *A. paniculatus*, Tipton (B). *A. p.* var. *simplex*, Tippecanoe (B), Tipton (B). *A. pilosus*, Madison (B), Shelby (B). *A. praealtus*, Clinton (B). *A. p.* var. *angustior*, Miami (B).

Erigeron annuus, Hamilton (B), Shelby (B). *E. canadensis*, Miami (B), Tipton (B). *E. divaricatus*, Vanderburgh (IU). *E. philadelphicus*, Elkhart (B). *E. strigosus* (*E. ramosus*, see Nomenclatorial Changes), Clinton (B), Tippecanoe (B). *Silphium integrifolium*, Huntington (Hu). *S. perfoliatum*, Boone (B), Hendricks (B), Madison (B), Shelby (B). *Ambrosia coronopifolia*, Elkhart (B). *A. elatior*, Clinton (B), Elkhart (B), Hamilton (B), Madison (B). *A. trifida*, Cass (B). *Xanthium italicum*, Tipton (B). *Heliopsis helianthoides*, Clinton (B), Madison (B). *Eclipta alba*, Shelby (B). *Rudbeckia hirta*, Boone (B). *R. triloba*, Shelby (B). *Ratibida pinnata*, Miami (B). *Helianthus annuus*, Elkhart (B), Tipton (B). *H. decapetalus*, Tipton (B), Vanderburgh (IU). *H. divaricatus*, Tipton (B). *H. giganteus*, Miami (B), Newton (B). *H. grosseserratus*, Huntington (Hu). *H. microcephalus*, Hamilton (B). *H. mollis*, Clinton (B), Elkhart (B). *H. petiolaris*, Elkhart (B), Tippecanoe (B). *H. tuberosus*, Vanderburgh (IU).

Actinomeris alternifolia, Madison (B), Shelby (B). *Coreopsis tripteris* var. *deamii*, Elkhart (B). *Bidens bipinnata*, Tipton (B). *B. cernua*, Elkhart (B), Shelby (B). *B. comosa*, Shelby (B), Tipton (B). *B. coronata*, Madison (B). *B. frondosa*, Shelby (B), Tippecanoe (B). *B. vulgata*, Clinton (B), Hamilton (B), Howard (B), Shelby (B), Tippecanoe (B). *Helenium autumnale*, Huntington (Hu), Shelby (B). *Anthemis cotula*, Vanderburgh (IU). *Achillea millefolium*, Hendricks (B). *Matricaria matricarioides*, Hendricks (B), Jennings (B). *Tanacetum vulgare*, Brown (B). *Artemisia annua*, Shelby (B). **A.* **carruthii** Wood (see Flora, p. 1102), coll. by E. D. Hull. Lake (IU). *A. gnaphalodes*, Tippecanoe (B). *Erechtites hieracifolia*, Tipton (B). *Cacalia atriplicifolia*, Hamilton (B), Tipton (B). *C. muhlenbergii*, Hendricks (B). *C. suaveolens*, Hamilton (B), Tipton (B). *Senecio glabellus*, Marion (B). *Arctium minus*, Carroll (B).

Cirsium altissimum, Huntington (Hu), Miami (B). *C. arvense*, Clinton (B), Tipton (B). *C. a.* var. *mite*, Miami (B). *C. discolor*, Huntington (Hu), Marion (B). *C. muticum*, Huntington (Hu). *C.* **undulatum**, see Flora, p. 1104. Coll. by C. M. Ek. Elkhart (B), (D). *C. vulgare*, Miami (B). **Centaurea vochinensis*, Shelby (B), (D). *Cichorium intybus*, Elkhart (B), Hamilton (B), Johnson (Fr), Marion

(B), Ohio (B), Shelby (B). *Krigia biflora*, Jennings (B). *Tragopogon porrifolius*, Miami (B). *T. pratensis*, Clinton (B), Hendricks (B). *Taraxacum laevigatum*, Vanderburgh (IU). *T. palustre* var. *vulgare*, Elkhart (B), Hendricks (B). *Sonchus oleraceus*, Elkhart (B), Miami (B). *Lactuca canadensis* var. *typica*, Carroll (B). *L. c.* var. *integrifolia*, Boone (B). *L. floridana*, Cass (B). *L. saligna*, Carroll (B), Cass (B), Hamilton (B). *L. scariola*, Hamilton (B), Hendricks (B). *L. s.* var. *integrata*, Carroll (B), Miami (B). *L. villosa*, Miami (B). *Hieracium canadense*, Cass (B).

Nomenclatorial Changes

The following changes in names of Indiana plants are considered by the committee to be likely of acceptance by taxonomists generally. Other published changes have recently appeared in the literature but are temporarily withheld from this list awaiting further evidence of their merit or likelihood of general acceptance.

Potamogeton panormitanus vars. *major* and *minor* to *P. pusillus* L. Rhodora 43:528. 1941.

Cyperus ferruginescens Boeckl. to *C. odoratus* L. Checklist Plants Washington-Baltimore Area, p. 22. 1941.

Cyperus filiculmis var. *macilentus* to *C. filiculmis* Vahl. Plants Washington-Baltimore Area, p. 22. 1941.

Cyperus inflexus to *C. aristatus* Rottb. loc. cit.

Cyperus mesochorus to *C. schweinitzii* Torr. Rhodora 44:58. 1942.

Cyperus ovularis to *C. o.* var. *sphaericus* Boeckl. Rhodora 44:81-83. 1942.

Cyperus strigosus var. *multiflorus* to *C. deamii* O'Neill. Rhodora 44:81-83. 1942.

Kyllingia pumila to *Cyperus densicaespitosis* Mattf. & Kukenth. Pflanzenr. 20:597. 1936.

Carex alata Torr. to *C. alata* T. & G. Rhodora 43:334. 1941.

Carex jamesii Schwein to *C. jamesii* T. & G. Rhodora 43:334. 1941.

Carex lasiocarpa to *C. l.* var. *americana* Fern. Rhodora 44:304. 1942.

Carex riparia var. *lacustris* to *C. lacustris* Willd. Rhodora 44:319-321. 1942.

Carex rostrata to *C. inflata* var. *utriculata* (Boott) Druce. Rhodora 44:324-331. 1942.

Lemna cyclostasa to *L. valdiviana* Philippi. Castanea 6:86. 1941.

Carya pecan to *C. illinoensis* (Wang.) K. Koch. Jour. Arnold Arboretum 22:571. 1941.

Ulmus racemosa to *U. thomasi* Sarg. Rehder, Trees and Shrubs 2ed. 190. 1940.

Desmodium acuminatum to *D. glutinosum* (Muhl.) Wood. Wood's Classbook 1845. Rhodora 44:279-280. 1942.

Desmodium glabellum to *D. humifusum* Beck. Plt. Wash.-Balt. Area, p. 80. 1940.

Lespedeza capitata var. *longifolia* to *L. c.* var. *stenophylla* Bissell & Fernald. Rhodora 43:579. 1941.

Geranium bicknellii previously changed to *G. nemorale* var. *bicknellii*, restore to *G. bicknellii* Britt. Rhodora 44:91. 1942.

Hibiscus moscheutos to *H. palustris* L. Rhodora 44:278. 1942.

Hibiscus palustris to *H. moscheutos* L. Rhodora 44:278. 1942.

Cornus asperifolia to *C. drummondii* Meyer. Amer. Midland Nat. 27:259-261. 1942.

Convolvulus repens to *C. sepium* var. *repens* (L.) Gray. Rhodora 41:421. 1939.

Myosotis virginica to *M. verna* Nutt. Rhodora 43:636-637. 1941.

Viburnum pubescens vars. *deamii* and *indianense* to *V. dentatum* var. *deamii* (Rehd.) Fern. Rhodora 43:649. 1941.

Aster exiguus to *A. ericoides* var. *prostratus* (Kuntze) Blake. Rhodora 32:138. 1930.

Aster junceus to *A. junciformis* Rydb. Amer. Midland Nat. 26:411. 1941.

Aster oblongifolius to *A. o.* var. *angustatus* Shinners. Amer. Midland Nat. 26:418. 1941.

Erigeron ramosus to *E. strigosus* Muhl. Plt. Wash.-Balt Area, p. 101. 1941.

Deletions

The following deletions should be made from the state flora catalog. *Spermolepis inermis*, Cass: report should have been Tippecanoe. *Aster oblongifolius* var. *rigidulus*, Tippecanoe: drop from flora.

Additional Species Added to the Deam Herbarium

The following species previously reported in other herbaria for certain counties have been added to the Deam Herbarium since the last report.

Poa autumnalis, Jefferson. *Alopecurus carolinianus*, Jennings. *Eragrostis hypnoides*, De Kalb. *Setaria lutescens*, Kosciusko. *Cyperus erythrorhizos*, De Kalb. *Quercus borealis* var. *maxima*, Whitley. *Q. imbricaria*, Lagrange. *Q. macrocarpa*, Lagrange. *Gentiana puberula*, Newton. *Agastache scrophulariaefolia*, Kosciusko. *Solidago speciosa*, Newton.

State Flora Committee: CHARLES C. DEAM, *Chairman*
RALPH KRIEBEL
T. G. YUNCKER
R. C. FRIESNER, *Secretary*

Meeting of Plant Taxonomists

The taxonomists of Indiana met Saturday forenoon, October 31, 1942 following the sessions of the Indiana Academy of Science in the Biology building at the University of Notre Dame. The session was well attended considering the travel situation.

The chairman, T. G. Yuncker of DePauw University presided.

R. C. Friesner of Butler University, chairman of the committee on Plant Distribution Records for the state of Indiana gave a report showing the additions to the flora of many of the counties. A number of state additions were reported. The report also indicated that there is a great deal of interest manifested by the taxonomists of the state in a more detailed record of the flora and floral distribution of Indiana.

Scott McCoy, director of Halleday Park Botanical Garden, Indianapolis, gave an illustrated talk on "Bringing them back alive" showing the general plan of the garden and many colored pictures of the various sections, individual plants, and groups.

Ralph M. Kriebel, of the U. S. Soil Service, Bedford, gave his experiences botanizing on the Cumberland plateau and Cedar glades of Tennessee. He showed a number of pressed specimens of characteristic plants illustrating the flora of that region as well as a number of colored pictures on the screen.

Fred A. Loew of Huntington College reported some observations of Individual differences in Blue Ash and Amsonia as seen in Huntington College Botanical Garden. A number of pressed specimens were shown to illustrate the differences.

The matter of listing the unusually interesting plant areas in Indiana was discussed. This is a rather new phase of flora record in which considerable interest was shown. After an interesting discussion a committee was appointed by request of the group to study this idea and report at the next meeting. The following constitute the committee: Scott McCoy, chairman, Charles Deam, R. C. Friesner, and Ralph Kriebel.

The nominating committee reported the nomination of Scott McCoy, chairman, and Fred A. Loew, secretary for 1943. The report was adopted.

CHEMISTRY

Chairman: K. N. CAMPBELL, University of Notre Dame

Mr. Edward J. Hughes, Eli Lilly Co., Indianapolis, was elected chairman of the section for 1943.

Some modern aspects of the Dumas method for the determination of nitrogen. K. N. CAMPBELL, University of Notre Dame.—The Dumas method is the oldest, and still one of the best methods for analyzing organic compounds for nitrogen. The older macro technique, however, is not much used at present because of the relatively large sample required, and because of the time needed for a single determination. The Pregl micro method requires a special balance and the technique needed is too complicated to teach, in general, to students who have had no experience with more rugged methods. The more recently developed semi-micro methods are less sensitive to errors than is the Pregl method. A five place balance is, however, desirable and considerable technique is needed. For these reasons a hemi-macro method has been devised for teaching undergraduate students. This method is more rugged than the semi-micro and micro methods, but is more rapid and uses a smaller sample than the macro method. A description of the method is given. The results appear to be as accurate as those obtained by other methods.

Notes on the cause of color in precious stones. FRANK B. WADE, Shortridge High School, Indianapolis.—The best thought in modern physics attributes optical effects among the elements to the valence electrons. Evidence is presented to show that this is the case in the matter of color effects in gems. It is suggested that we are probably dealing with a *resonance* effect among the outer energy level electrons of the atoms of these transition elements. Relatively slight changes in the energy content of these coloring elements make marked changes in the color effects

Assay for Menthone in Oil of Peppermint

LAWRENCE H. BALDINGER, University of Notre Dame

For the estimation of menthone in oil of peppermint, as well as for the quantitative determination of aldehydes and ketones in other essential oils, oximation with hydroxylamine hydrochloride in an alcohol medium with subsequent titration of the liberated hydrochloric acid appears to give the best results. Variations in menthone content of a sample of oil submitted to different laboratories may result from a number of factors, i.e., type of indicator, concentration of hydroxylamine solution, method of addition of solution, and temperature.

Kremers[1] was the first to publish a gravimetric method for the estimation of aldehydes and ketones with hydroxylamine hydrochloride. Walther[2] first used a volumetric procedure with hydroxylamine hydrochloride for determining citral in oil of lemon. Stillman and Reed[3] have published a summary of methods employed for the determination of aldehydes and ketones, as well as a method of their own invention.

Menthone is a ketone, $C_{10}H_{18}O$, which occurs with menthol, $C_{10}H_{19}OH$, in oil of peppermint. Also present in the oil are menthyl acetate, $C_{10}H_{19}C_2H_3O_2$, a mixture of terpenes, and small amounts of organic compounds related to or derived from these four essential components.[4]

Concerning the biogenesis of these compounds in peppermint, the reader is referred to a discussion by Hall[5] who has also included a brief history of the theories to explain the formation of these substances by the plant. Earlier investigators advanced the theory that menthone was formed in the plant by the oxidation of menthol and that oils distilled late in the season would show a high menthone content. Recently, however, Strauss[6] has stated: "Peppermint for oil production is best cut after full bloom has been reached, not at the beginning of flowering. In this way it is possible to obtain a maximum yield of oil with a menthone content not exceeding 15 per cent. According to Rutovskii and Travain[7] the menthol content of the plant increases during growth, whereas the menthone content decreases. It appears that, under the influence of the sunlight during the growth of the plant up to the time of full bloom, menthol is slowly formed from menthone, to which the bitter aftertaste of peppermint oil is due.

The author's observation on the menthone content of numerous samples of oil collected at different stages of growth agree with the find-

[1] Kremers, Pharm. Rev. **14**:76, 244 (1896); Pharm. Arch. **2**:81 (1899); **3**:9 (1900); J. Soc. Chem. Ind. **20**:16 (1901).

[2] Walther, Pharm. Zentralh., **40**:621 (1899); **41**:614 (1900).

[3] Stillman and Reed, Perfumery Essent. Oil Record, **23**:278 (1932).

[4] Power and Kleber, Pharm. Rundschau, **12**:157 (1894).

[5] Hall, Chem. Rev., **13**:479 (1933).

[7] Rutovskii and Travain, Riechstoff, Ind. **4**:124 (1929).

[6] Strauss, IV Congr. interna. plantes medicinals plantes essences, Paris, p. 270 (1931); through Schimmel Report, p. 45 (1933).

ings of Strauss. Apparently the biogenetic processes in the plant synthesize menthone as well as menthol and a phytochemical reduction changes the former substance into the corresponding alcohol menthol, as the plant matures. Although the significance of the observation can be questioned, it is interesting to note that the sum of the menthol and menthone percentage in oil of peppermint will be within the range of 75 to 85 per cent.

Experimental Procedure

The particular problem which constituted the basis for this report was to determine whether the constituents of oil of peppermint, other than menthone, would react with hydroxylamine hydrochloride to cause a variation in menthone content. For this purpose an artificial oil of peppermint was prepared by combining accurately-weighed amounts of alpha-pinene, 13.87%, menthyl acetate 4.71%, menthol 51.16%, and menthone 30.26%, in proportions commonly found in natural oil of peppermint. The menthone was prepared by the oxidation of menthol with dichromic acid, the menthyl acetate by acetylation of menthol, the alpha-pinene by purification and distillation of oil of turpentine; the menthol was U. S. P. grade and was not subjected to further purification. The artificial oil as well as the pure components were subjected to oximation by two methods as listed below. The results are tabulated in Table I.

Method I. Weigh the dried substance to be analyzed into a glass-stoppered flask containing 10 ml. of alcohol. Add 30 ml. of N/2 KOH and 10 ml. of 1 N hydroxylamine hydrochloride solution. Repeat on a blank omitting the oil. Shake vigorously at frequent intervals for one hour. Titrate the excess KOH with N/2 H_2SO_4, using 8 drops of brom-phenol-blue indicator (0.4% solution). Color change is from blue to green to yellow. Titrate the blank to full yellow and match the sample to the blank. Back-titrate the blank to a pale-green with KOH. Match the sample with this. Subtract the amount used for the back-titration from the original titration as a basis for the calculation. Subtract the number of ml. of H_2SO_4 used for the blank. This represents the number of ml. of KOH used to neutralize the HCl liberated. One ml, of N/2 KOH is equivalent to 0.077 grams of ketone.

$$\% \text{ Menthone} = (7.7 \times \text{ml. N/2 KOH}) \div \text{weight of sample}$$

Method II. Weigh the dried substance to be analyzed into a glass-stoppered flask containing 5 ml. of alcohol; add 20 ml. of 1 N hydroxylamine hydrochloride, 0.4 ml. dimethyl yellow indicator, and add N/2 KOH until the red color changes to yellow. Place the flask in a water bath at 75°-80° C. and neutralize the liberated HCl with N/2 KOH at five-minute intervals; after forty minutes, complete the titration to the full yellow color of the indicator and record the burette reading.

Two determinations are carried on side by side, using separate burettes, and the first one completed, plus an excess of one ml. of N/2 KOH is used as the color standard for the end point of the duplicate. A correction factor is necessary because the end-point of the titration

occurs at a pH different from that of normal hydroxylamine hydrochloride. The percentage composition is determined from the duplicate. An additional correction factor must be used if the KOH used is not exactly N/2.

$$\% \text{ Menthone} = (7.7 \times 1.008 \times \text{ml. N/2 KOH}) \div \text{weight of sample}$$

If the apparent menthone content for the amount of each of the constituents of the artificial oil of peppermint is calculated, based on the values given in Table I, it will be observed that the sum of these apparent menthone contents will agree fairly well with the menthone assay for the artificial oil, as shown in the following example.

As determined by the two methods, the average per cent of apparent ketone shown by alpha-pinene is 4.42%, by menthone 98.55%, by menthol 2.3%, and by menthyl acetate 60.25%. Using these figures, the apparent menthone in the artificial oil of peppermint is calculated to be 34.45%.

The average experimental value for the menthone content obtained in the analysis of the artificial oil is 34.15%.

Conclusion

It is apparent that the presence of various components in oil of peppermint definitely affects the apparent menthone per cent, that the percentages of ester, menthol, and terpene must be considered in determining the pure menthone content. Other essential oils or mixtures of organic compounds on which oximation procedures may be performed will undoubtedly show the same variations in ketone or aldehyde content, depending upon the reactivity of the different constituents with hydroxylamine hydrochloride.

TABLE I. Apparent Menthone Content of Artificial Oil of Peppermint and of the Constituents of Artificial Oil of Peppermint.

Constituent	Per Cent Menthone Method I	Method II
Alpha-pinene	4.2	4.5
	4.4	4.3
	4.6	4.5
Menthyl Acetate	62.3	59.4
	60.1	61.5
	59.0	59.1
Menthone	99.3	98.3
	97.6	98.5
	98.4	98.7
Menthol	2.3	2.3
	2.3	2.3
	2.4	2.2
Artificial Oil of Peppermint. Calculated Menthone Content 30.26%	34.0	34.2
	33.9	34.1
	33.4	34.3

Preparation of Telluric Acid from Tellurium Dioxide by Oxidation with Potassium Permanganate

FRANK C. MATHERS, CHARLES M. RICE, HOWARD BRODERICK, and ROBERT FORNEY, Indiana University

General Statement

Tellurium dioxide, TeO_2, although periodically similar to sulfur dioxide, cannot be oxidized by nitric acid to the valence of six, i.e., to telluric acid, $H_2TeO_4.2H_2O$. Among the many stronger oxidizing agents that will produce this oxidation, potassium permanganate in a nitric acid solution is quite satisfactory. This paper gives directions and data for the preparation of telluric acid by this reaction.

The making of telluric acid is a desirable laboratory experiment because (1) tellurim dioxide is available in large quantities and is easily obtained, (2) the telluric acid is a stable compound, easily purified, easily crystallized, and non-corrosive, and (3) students are interested in experimenting with the rarer elements.

The small soluibility of telluric acid and the high solubility of both manganese and potassium nitrates in nitric acid[1] gives a sufficient difference in properties for successful purification by crystallization of the telluric acid.

Methods of Analyses

Tellurium dioxide can be volumetrically[2] titrated in a sulfuric acid solution by an excess of standard potassium permanganate, followed by enough standard oxalic acid to decolorize the excess of permanganate. The excess of oxalic acid must then be titrated by more of the permanganate.

The telluric acid can be titrated, like any ordinary monobasic acid,[3] (1911).
with standard sodium hydroxide using phenolphthalein as an indicator, if an equal volume of glycerine is added. If any nitric acid is present, it must be neutralized first with sodium hydroxide, using methyl orange as indicator. Test analyses on purified telluric acid showed that this method was satisfactory, although there were some small variations in the check determinations.

Preparation of Material

The lead and copper electrolytic refining plants have large stocks of crude tellurium dioxide. Some of this material which contained 84.8% of TeO_2 was treated with a slight excess of sodium hydroxide and filtered. This removed sand, dirt, iron and all the other things that were insoluble in alkalies. The sodium tellurite, Na_2TeO_3, in the filtrate was decomposed

[1] Mathers and Rice, this volume, p. 117 (1942).

[2] Brauner, J. Chem. Soc., **59**:238 (1891).

[3] Rosenheim and Weinheber, Z. Anorg. Chem., 69:266-9; Chem. Abst., 5:378

and tellurium dioxide was precipitated by addition of hydrochloric acid until almost neutral, and then by acetic acid until slightly acid. It was found best to allow the precipitate to stand a few days before washing (by decantation) and filtering. The filtered residue, after drying, was white, soft, bulky, chalky and pure tellurium dioxide.

Experimental

The quantities of the materials to be used and the conditions of operation in the preparation of the telluric acid are not critical. All that is needed is a slight excess of permanganate on tellurium dioxide in a hot solution containing sufficient nitric acid to prevent a permanent precipitation of much manganese dioxide. At the end of the reaction, sufficient hydrogen peroxide should be added to make the remaining manganese dioxide dissolve. The rest of the process is simply a crystallization of the telluric acid and its purification by recrystallization.

The equation for the reaction in strong nitric acide is:

$$5TeO_2 + 2KMnO_4 + 6HNO_3 + 2H_2O = 5H_2TeO_4 + 2KNO_3 + 2Mn(NO_3)_2.$$

If only a little nitric acid is present, the reaction seems to be:

$$3TeO_2 + 2KMnO_4 + 2HNO_3 + 2H_2O = 3H_2TeO_4 + KNO_3 + 2MnO_2.$$

Due to the necessity of purifying the telluric acid from the by-products of the reaction, the first reaction is preferable because a smaller ratio of permanganate is needed. The theoretical quantity of potassium permanganate for 10 gms. of tellurium dioxide is 3.95 gms. It was found desirable to use a little excess of the permanganate, to compensate for some loss of oxygen, if the permanganate was added too rapidly or without sufficient stirring.

After many preliminary experiments, which need not be discussed, the following quantities and conditions were chosen:

> Four grams of $KMnO_4$, dissolved in 100 ml. of H_2O, were added slowly, about 5 ml. at a time with vigorous stirring, to a boiling mixture of 10 gms. TeO_2, 40 ml. of HNO_3 and 100 ml. of water.

Some manganese dioxide was present during this entire process. It was possible, but not necessary, to cause the black manganese dioxide to react, except near the end, by boiling for a sufficient time after each addition of permanganate. The amount of manganese dioxide remaining in the reaction mixture at the end depends upon (1) the excess of permanganate used, (2) the rate of adding the permanganate, and (3) the time of boiling between additions of the permanganate.

As the insoluble tellurium dioxide was oxidized to the soluble telluric acid, the solution gradually became free of any precipitate except for some manganese dioxide.

After all the permanganate was added, the solution was kept at the boiling point for fifty minutes, in order to have maximum reaction of the manganese dioxide which remained from the excess of permanganate. Then enough hydrogen peroxide was added to make the remaining manganese dioxide go into solution.

The clear solution was evaporated to a weight of 60 grams and 10 ml. of HNO_3 were added; then the solution was allowed to crystallize for twenty-four hours, preferably at 10° C. The mother liquor yielded a second crop of crystals after evaporation to a weight of 25 gms. and the addition of 10 ml. of nitric acid.

These crystals, after uniting, were washed with three portions of 10 ml. each of nitric acid and drained as completely as possible after each washing. In later experiments, a centrifuge was found desirable in conducting this washing operation.

These crystals were purified by dissolving in 25 ml. of water after which 17 ml. of conc. nitric acid were added. The crystals, which formed after twenty-four hours, were washed three times with nitric acid as described above. These crystals were then recrystallized a third time in the same way. The nitric acid and water were removed from these final crystals by heating to about 100° C.

The final crystals had a purity of 99.85 per cent, and the overall material yield from the tellurium dioxide used was 77 per cent. If well formed crystals are desired, these crystals should be crystallized slowly from water—the solubility of the telluric acid in nitric acid is too small for large crystals to be produced easily. Also crystals from water solutions are more easily freed from solvent than those from nitric acid.

If a high material yield is not an aim of the work, it is recommended that the crystallizations should be from water, after one recrystallization from the nitric acid—strong nitric acid solutions are not pleasant to work with.

Crude tellurium dioxide can be used with equally good results, if the sand and other insoluble material is filtered out following the addition of the hydrogen peroxide.

The material yield could have been increased somewhat by reworking the mother liquors and by using still more concentrated nitric acid to reduce further the solubility of telluric acid.

Solubility of Telluric Acid in Aqueous Nitric Acid

FRANK C. MATHERS and CHARLES M. RICE, Indiana University

A very common step in the preparation of telluric acid, $H_2TeO_4.2H_2O$, is to precipitate it from aqueous solutions by adding strong nitric acid or by crystallizing it from nitric acid solutions. This small solubility of telluric acid in nitric acid makes possible a satisfactory separation from all of the impurities or by-products whose nitrates are sufficiently soluble in aqueous nitric acid; this is especially true of potassium nitrate and manganese nitrate which result from the oxidation of tellurium dioxide in nitric acid solution with potassium permanganate.

In researches on the preparation of telluric acid, data on the solubility given in this paper had to be determined as it could not be found in the literature. This solubility data was determined by saturating various concentrations of nitric acid with an excess of carefully purified telluric acid. Glass stoppered bottles, containing the materials, were suspended in a water bath at 25° ± .2° C. and were gently agitated for twelve hours. The telluric acid in these saturated solutions was determined by evaporating a one ml. sample and weighing. The nitric acid in each saturated solution was determined by titrating one ml. using methyl orange as an indicator. Telluric acid is so slightly ionized that this titration is accurate.

TABLE I. Values Obtained for the Determination of the Solubility of Telluric Acid in Nitric Acid.

Wt. of $H_2TeO_4.2H_2O$ in 100 cc. of Solution	Grams of HNO_3 in 100 cc. of Solution
0.06 gms.	93.93 gms.
0.36	75.16
0.97	57.39
10.22	27.40
19.42	18.52
35.8	8.63

In plotting these data, curves for potassium nitrate, with data taken from the literature, were included to show that a separation of telluric acid from potassium nitrate should be successful. The data on manganese nitrate show very great solubility in nitric acid.

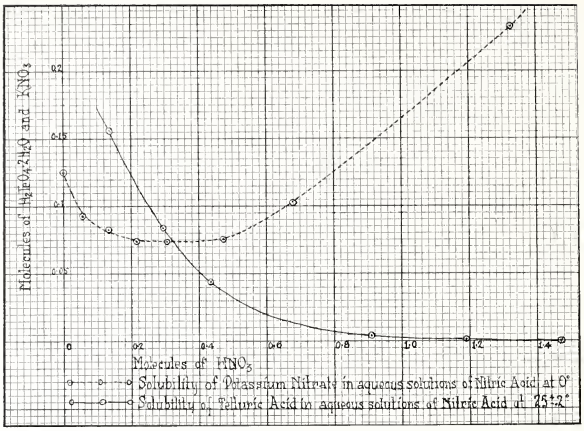

Fig. 1.

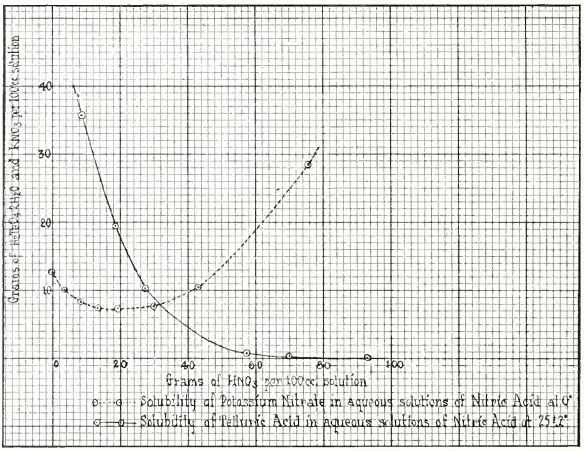

Fig. 2.

Conclusion

In ordinary concentrated nitric acid, the solubility of telluric acid is less than 1 gm. per 100 ml., and, in 40% HNO_3, the solubility is about 5 gms. per 100 ml.

Very complete recovery of telluric acid is easily accomplished by adding concentrated nitric acid to concentrated aqueous solutions of telluric acid. The solubility of telluric acid in water is quite high—40 gms. per 100 ml. at 25°C.

The impurities in the adhering mother liquor can be removed by washing with concentrated nitric acid without the loss of appreciable quantities of the telluric acid.

The Utilization of Aliphatic Nitro Compounds IX. Preparation and Properties of Aliphatic Nitroalcohols and Aminoalcohols*

Ed. F. Degering and R. I. Hoaglin, Purdue University

During the past few years the nitroparaffins have become available in quantities sufficiently large to permit a thorough investigation of their properties. Hass and Vanderbilt (1) studied the condensation of aldehydes with nitroparaffins, and Degering and Johnson (2) investigated the reduction of nitroalcohols to the corresponding amino compounds.

The work reported in this paper is a continuation of both the nitroparaffin-aldehyde condensation and the reduction of nitroparaffins with respect to the production of four nitroalcohols and the corresponding aminoalcohols. The nitroalcohols prepared and studied are: (1) 2-methyl-2-nitro-3-pentanol, (2) 2-methyl-2-nitro-3-hexanol, (3) 3-methyl-3-nitro-4-heptanol, and (4) 2-nitro-1-hexanol. These compounds were prepared by the use of formaldehyde, propionaldehyde, or butyraldehyde with 1-nitropropane, 2-nitropropane, 2-nitrobutane, and 1-nitropentane.

1. *Condensation product of 2-nitropropane: 2-Methyl-2-nitro-3-pentanol.*

Into a 500 ml. three-necked flask, equipped with a mercury seal and a motor-driven stirrer, were placed 89 g. (1 mol) of 2-nitropropane, 25 ml. of 95% ethyl alcohol, and 4 ml. of 10 *N* sodium hydroxide. Then 60.9 g. (1 mol + 5% x's) of propionaldehyde, at slightly below room temperature, was added dropwise with vigorous agitation. Addition of the aldehyde was complete in about 40-50 minutes. Five milliliters of water was added to give a clear solution. The solution was allowed to stand six days at room temperature, and the alkali then neutralized with an equivalent amount of hydrochloric acid. The precipitated sodium chloride was filtered off, and the ethyl alcohol stripped from the solution at 30 mm. pressure (water pump). Additional sodium chloride, which precipitated during this operation, was filtered off and the solution fractionated under vacuum on a modified Podbielniak column. The conversion was 46-52%, based upon the quantity of 2-nitropropane used. The boiling point was 94.5° C. at 10 mm. pressure. The crude nitroalcohol was washed with 10 ml. of 33⅓% sodium bisulfite solution, dried with anhydrous magnesium sulfate, and redistilled. The nitroalcohol thus obtained was almost water-white.

2. *Condensation product of 1-nitropentane: 2-nitro-1-hexanol.*

1-Nitropentane was condensed with formaldehyde, the best of two runs giving a 73% conversion, based upon the 1-nitropentane. High yields are ordinarily obtained with a primary nitroparaffin.

* This is an abstract from a portion of a thesis submitted to the Faculty of Purdue University by R. I. Hoaglin in partial fulfillment of the requirements for the degree of Master of Science, June, 1938.

These four nitroalcohols prepared by this nitroparaffin-aldehyde condensation have the physical constants listed in Table I.

Table I—Physical Constants of Some Nitroalcohols

Nitroalcohol	Prepared from	B.P.° C.	Specific Gravity 25° C.	Refractive Index 20° C.
2-methyl-2-nitro-3-hexanol	2-Pr.NO_2+C_3H_7CHO	86.5 at 5 mm.	1.0435	1.4494
3-methyl-3-nitro-4-heptanol	2-Bu.NO_2+C_3H_7CHO	117 at 10 mm.	1.0281	1.4534
2-methyl-2-nitro-3-pentanol	2-Pr.NO_2+C_2H_5CHO	94.5 at 10 mm.	1.0748	1.4488
2-nitro-1-hexanol	1-Am.NO_2+HCHO	102.9 at 5 mm.	1.0556	1.4451

In order to obtain the nitroalcohols in maximum yields, the aldol polymerization must be suppressed. All the aliphatic aldehydes possessing *alpha* or (4-position) hydrogen atoms undergo this latter reaction with ease, necessitating some means of keeping the extent of this polymerization at a minimum. Since both the nitroparaffin-aldehyde condensation and aldol polymerization take place in an alkaline medium, they are completing reactions. The aldol polymerization may be minimized by keeping the reaction mixture in a homogeneous state at all times. The volume of solvent alcohol used should be sufficient to insure this homogeneity. The aldehyde must be added in such a manner that there will be an excess of nitroparaffin in the reaction mixture at all times. Before recovering the nitroalcohol from the reaction mixture, the alkali should be carefully neutralized. By observation of these precautions, the formation of the aldol-type products may be minimized.

During the recovery of the nitroalcohol, nitroolefins may be produced. This reaction takes place by the elimination of a molecule of water from the nitroalcohol:

$$R.CHNO_2.CHOH.R \rightarrow R.C(NO_2):CH.R + H_2O.$$

This undersirable side reaction may be avoided in general by working at lower temperatures. Nitroölefins have distinct lachrymatory properties and are easily polymerized to highly colored substances.

Reduction of the Nitroalcohols to the Corresponding Aminoalcohols

The nitroalcohols made, with one exception, were hydrogenated to the aminoalcohols. These products should have properties similar to those of the ethanolamines and, consequently, have commercial application. Degering and Johnson (2) hydrogenated nitroglycols and nitroalcohols, but no attempt was made to purify the reduction products obtained from the nitroalcohols, which contained less than six carbon atoms. It has been found that the nitroalcohols are unstable under most reducting conditions (1, 2).

The apparatus used for this part of the work was a bomb built by the Parr Instrument Company. It was of 500 ml. of capacity and was

capable of withstanding a pressure of 6,000 pounds per square inch. The reductions were carried out at room temperature, the bomb being rocked at the rate of thirty times per minute. The hydrogen was obtained from an industrial cylinder (2,000 pounds pressure or less).

The catalyst is prepared by treating powdered Raney alloy (50% Ni and 50% Al) with 25% sodium hydroxide to dissolve the aluminum. The next step consists in washing the catalyst with water until the solution is no longer basic to phenolphthalein. A final wash is made with 45% ethanol. The amount of catalyst weighed out for each run is twice the weight desired, due to removal of half the weight by solution in sodium hydroxide.

The nitroalcohol, solvent alcohol, and catalyst are placed in the bomb, and the mixture is shaken at the desired hydrogen pressure. When the pressure becomes constant for a period of an hour, showing that no further hydrogenation is taking place, the agitation is discontinued. The catalyst is filtered from the solution and an aliquot portion titrated with standard acid to determine conversion to base. After fractionation, the aminoalcohol is dried with anhydrous potassium carbonate and redistilled. Table II summarizes the physical constants of the three aminoalcohols produced.

TABLE II.

Aminoalcohol	B. P. °C.	Specific Gravity 26° C.	Refractive Index 20° C.
2-Amino-2-methyl-3-pentanol	50 at 4 mm.	0.9824	1.4508
2-Amino-2-methyl-3-hexanol	63.5 at 5 mm.	0.9782	1.4461
3-Amino-3-methyl-4-heptanol	98 at 4¼ mm.	0.9810	1.4366

Although the conversions to base were high (85-93%), the yields of aminoalcohols obtained were low, the highest being 31%.

The aminoalcohols obtained are viscous, high boiling, water-white liquids, possessing an odor much less penetrating than that of an aliphatic amine or ammonia.

Summary

Certain nitroparaffins have been condensed with certain aliphatic aldehydes in a basic solution to give the aliphatic nitroalcohols.

The nitroalcohols so formed have been reduced to the corresponding aminoalcohols by catalytic hydrogenation.

The compounds prepared were: 2-methyl-2-nitro-3-hexanol, 3-methyl-3-nitro-4-heptanol, 2-methyl-2-nitro-3-pentanol*, 2-nitro-1-hexanol*, 2-amino-2-methyl-3-hexanol*, 3-amino-3-methyl-4-heptanol*, 2-amino-2-methyl-3-pentanol*. The starred compounds represent new composition of matter.

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The Reaction Between Silver Amidosulfonate and the Alkyl Iodides

W. W. Binkley[1] with Ed. F. Degering, Purdue University

Methyl amidosulfonate was prepared from methyl iodide and silver amidosulfonate in 1911 by Ephraim and Lasocky (1). The purpose of the present work is to show that the procedure used by these workers is unsuitable for the preparation of the higher alkyl esters of amidosulfonic acid, what products are formed, and what course the reactions between the higher alkyl iodides and silver amidosulfonate follows. The procedure used in the experimental part of this work is essentially the same as that used by Ephraim and Lasocky.

Experimental

The Reaction Between Methyl Iodide and Silver Amidosulfonate. Ten grams of silver amidosulfonate (ground to pass a 100 mesh screen), 25 ml. of absolute ethyl ether, and 6.5 g. of methyl iodide were added to a flask equipped for stirring. After 24 hours of agitation at room temperature, the reaction products were transferred to a weighed extraction thimble and extracted for 6 hours in a Soxhlet with ethyl ether and then for 6 hours with absolute methanol. The contents of the thimble were washed with 200 ml. of hot distilled water. This final residue was dried and weighed as AgI. The results are included in Table I.

The Reaction Between Ethyl Iodide and Silver Amidosulfonate. Ten grams of silver amidosulfonate (ground to pass a 100 mesh screen), 25 ml. of absolute ethyl ether, and 7.2 g. of ethyl iodide were agitated at room temperature for 24 hours. The reaction products were transferred to a weighed thimble and extracted for 24 hours in a Soxhlet with ethyl ether. The contents of the thimble was then washed with 200 ml. of hot distilled water. This final residue was dried and weighed as AgI. The results are listed in Table I.

Table I.—Analytical Results

Experiment	Alkyl Iodide†	AgI Formed	Amount of Reacted Iodide	Ether Extract	Alcohol Extract	$HOSO_2NH_2$ Found
		g.	g.‡	g.	g.	g.
1.	Methyl	7.2	4.3	0.3	3.2	0.0
2.	Methyl	7.0	4.2	0.3	2.8	0.0
3.	Ethyl	9.5	6.2	1.8	3.7	0.0
4.	Ethyl	9.4	6.2	1.8	1.8	1.0
5.	Ethyl	9.5	6.2	2.0	0.8	1.4
6.	Ethyl	9.5	6.2	2.4	..	1.9
7.	Ethyl	9.4	6.2	2.3	..	1.8
8.	*n*-propyl	3.9	2.8	1.1	..	0.7
9.	*n*-propyl	3.9	2.8	1.2	..	0.8

† Slightly less than 1/20 mole of alkyl iodide was used.

‡ The amount of reacted alkyl iodide was calculated from the amount of AgI formed.

[1] Present address, Ohio State University, Columbus, Ohio.

The Reaction Between n-Propyl Iodide and Silver Amidosulfonate. This reaction was conducted in the same manner as the reaction between ethyl iodide and silver amidosulfonate. The 7.2 g. of ethyl iodide were replaced by 7.8 g. *n*-propyl iodide. The extraction with ethyl ether required only 8 hours and 400 ml. of hot distilled water were used in the subsequent washing. The results are given in Table I.

Discussion

Good yields of methyl amidosulfonate (based on the amount of AgI formed) can be obtained from methyl iodide and silver amidosulfonate by the procedure of Ephraim and Lasocky (Expts. 1 and 2). When the reaction products of ethyl iodide and silver amidosulfonate were extracted 8 to 12 hours with ethyl ether, ethyl N,N-diethylamidosulfonate was isolated (cf. Expts. 3, 4, 5). If the products of this reaction were extracted 24 hours with ethyl ether, the theoretical amount of ethyl N,N-diethylamidosulfonate (based on the amount of ethyl iodide that reacted) was formed to satisfy Equation I (cf. Expts. 6 and 7).

(I) $3\ C_2H_5.I + AgO.SO_2.NH_2 \longrightarrow C_2H_5O.SO_2.N(C_2H_5)_2 + 2\ HO.SO_2.NH_2 + 3\ AgI.$

When the ethyl ether extraction was followed by 6 hours extraction with absolute ethyl alcohol, all the amidosulfonic acid formed in the reaction was converted to ethyl ammonium sulfate (cf. Expt. 3 and Equation II):

(II) $C_2H_5.OH + HO.SO_2.NH_2 \longrightarrow C_2H_5O.SO_2.ONH_4$

If the ether extraction was followed by washing the residue with two 25 ml. portions of hot absolute ethyl alcohol, a mixture of ethyl ammonium sulfate and amidosulfonic acid was obtained with a composition approximating ethyl amidosulfonate (2) (cf. Expt. 4). When 50 ml. of cold absolute ethyl alcohol was used for the washing instead of the two 25 ml. portions, a mixture containing amidosulfonic acid was obtained (cf. Expt. 5). When extraction with ethyl alcohol was replaced by washing with hot distilled water, the amount of amidosulfonic acid found approached the theoretical value required by Equation I (cf. Expts. 6 and 7). The reaction between *n*-propyl iodide and silver amidosulfonate followed the same course as the reaction between ethyl iodide and silver amidosulfonate (cf. Equation I). The amount of amidosulfonic acid was equal to the expected theoretical value (based on the amount of *n*-propyl iodide that reacted). The weight of the residue from the ether extraction was equal to the theoretical value for *n*-propyl N,N-di-*n*-propylamidosulfonate (cf. Expts. 8 and 9).

Summary

Good yields of methyl amidosulfonate were obtained from methyl iodide and silver amidosulfonate by the procedure of Ephraim and Lasocky. The reactions between ethyl and *n*-propyl iodides and silver amidosulfonates do not give the corresponding esters of amidosulfonic

acid. The corresponding esters of *N,N*-dialkylamidosulfonic acid and amidosulfonic acid were formed according to the following equation:

$$3\ R.I + 3\ AgO.SO_2.NH_2 \longrightarrow RO.SO_2.NR_2 + 2\ HO.SO_2.NH_2 + 3\ AgI.$$

This appears to be another interesting case of preferential alkylation of the nitrogen atom over that of the oxygen atom, which may be explained by the following postulated system:

$$Ag.O.SO_2.NH_2 \rightleftarrows Ag^+ {}^-O.SO_2.NH_2 \rightleftarrows HO.SO_2.NH^- + Ag^+.$$

in which the alkyl iodide reacts with either of the postulated ions. The salt may exist, moreover, according to Hennion, as a chelate complex in which the bond on either side of the silver atom might become activated.

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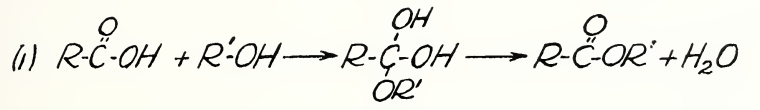
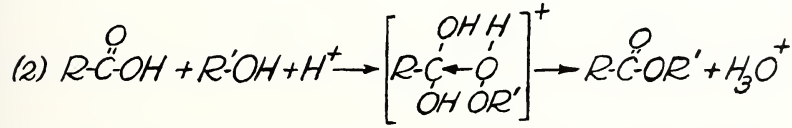
Some Studies in Esterification

G. F. Hennion and R. R. Vogt, University of Notre Dame

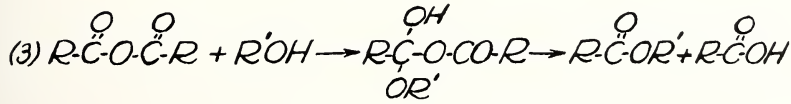
Recent publications (1, 2) from this laboratory have shown that the rate of reaction of hydrogen halides with olefins in dilute solution is markedly influenced by the nature of the solvent. Dilute solutions of hydrogen chloride and bromide add to cyclohexene, 3-hexene and alpha-pinene very slowly, if at all, in ether and dioxane and very rapidly in heptane. This effect is attributed to the electron-donor properties of the solvent. Thus the association or non-association of HX with the solvent has a tremendous effect on the reaction rate. Ether, dioxane and like solvents behave like bases, neutralizing the hydrogen halide, as it were, thereby retarding the olefin addition reaction.

We have been interested in determining if this "solvent effect" might be obtained in other organic reactions, e.g., in esterification. It is generally accepted (3) that an addition complex is intermediate in the ordinary metathetic reaction of carboxylic acids with alcohols. The addition complex, which yields ester by cleavage, may be considered to form by double bond addition as shown in the following equations:





Presumably the esterification of an acid anhydride goes through a similar mechanism, cleavage of the intermediate yielding ester and acid.



On this basis esterification might well be expected to show the solvent effect previously observed for olefin reactions. Therefore a series of experiments was conducted to compare the relative reaction rates of 0.05*M* acetic anhydride with 0.05*M* methanol in various solvents at 25° C. The anhydride was selected, rather than the acid, to prevent the separation of water and to assure a sufficiently rapid reaction for convenient measurement. One-hundred-ml. samples of 0.1 molar methanol and 0.1 molar acetic anhydride were prepared by direct weighing and placed in a constant temperature bath at 25°. After about thirty minutes

the two solutions were mixed quickly and the combined solution returned to the bath for the duration of the reaction. Ten-ml. samples were withdrawn periodically and titrated immediately with 0.1*N* sodium hydroxide, using bromthymol blue as an indicator. It was found possible to titrate unreacted anhydride and acid formed without appreciable hydrolysis of ester. This was confirmed by titrating a variety of blank samples, containing methyl acetate and acetic anhydride, but no methanol.

The solvents employed may be listed in the order of decreasing rate of esterification as follows: heptane, benzene, toluene, xylene, chloroform, carbon tetrachloride, nitrobenzene, dioxane, methyl acetate, 10% ether in heptane, ether. The reaction rate curves are shown in Figure 1.

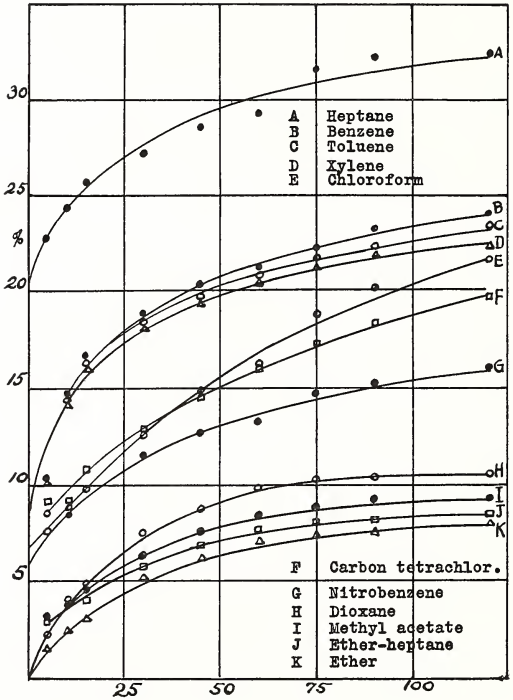


Fig. 1. Vertical scale gives per cent methanol reacted. Horizontal scale gives time in minutes.

While it is not possible to account for these results completely, it is likely that the decreased rate in donor solvents is due largely to solvation of methanol molecules by hydrogen bonding with solvent molecules. The decreasing rate in all solvents may be attributed not only to the decreasing concentration of the reactants, but also to the retarding effect of the accumulating methyl acetate. However, this does not account for the slowing down of the esterification in donor solvents after about fifty minutes. The acetic acid formed may possibly retard the reaction by forming a complex with acetic anhydride. The difference in the rates in heptane and in the aromatic hydrocarbons may indicate that the latter are involved in some weak association with one of the reactants, or that

methanol itself is associated to different extents in these solvents. At any rate it appears safe to state that if methanol and acetic anhydride could be reacted entirely unsolvated and unassociated, the reaction rate would be far greater than was observed in these studies.

On the basis of these data we were led to believe that the reaction of methanol with acetic acid (1:1) might be driven to completion, or at least far beyond the normal equilibrium point, if the reaction products, methyl acetate and water, could be forced to coordinate preferentially with some other electron acceptor. Boron trifluoride obviously is such a reagent. It forms stable coordination complexes with both methyl acetate and water; the complex with methanol is very acidic (4) and thus catalyzes the normal esterification.

A second series of experiments was therefore carried out to study the effect of boron fluoride when used in a quantity sufficient to coordinate completely with the reaction products. In a typical experiment one and one-half moles of boron fluoride was absorbed by a mixture of one mole of methanol and one mole of acetic acid, according to the following equation:

(4) $2CH_3\text{-}COOH + 2CH_3OH + 3BF_3 \rightarrow 2CH_3\text{-}COOCH_3.BF_3 + BF_3.2H_2O$

The methyl acetate-boron fluoride complex was fractionated from the boron fluoride dihydrate at reduced pressure. The crude product, b.p. 70-95° at 100 mm., m.p. 58.8°, was obtained in 96.2% yield. Upon redistillation the pure product, m.p. 60°, was obtained in 82.1% yield.

Methyl acetate was recovered from the boron fluoride complex by treatment with two equivalents of glacial acetic acid, followed by fractional distillation at atmospheric pressure. The yield of ester recovered was 98.6% based on the following equation:

(5) $CH_3\text{-}COOCH_3.BF_3 + 2CH_3\text{-}COOH \rightarrow CH_3\text{-}COOCH_3 + BF_3.(CH_3\text{-}COOH)_2$

Allowing for mechanical losses in distillation, etc., it is evident that methanol may be esterified completely by one equivalent of acetic acid if a sufficient quantity of boron fluoride is used. Substantially similar results have been obtained in the esterification of ethyl alcohol.

Acknowledgment. The authors express their gratitude to Messrs. Francis J. Herrmann and David J. Lieb who performed the experiments discussed in this paper.

Summary

Data are presented to show that large amounts of electron-donor and electron-acceptor substances have directly opposite effects in the esterification of methanol. The reaction with acetic anhydride at 25° was found to be slow and incomplete in either dioxane or ether solution and far more rapid in heptane. On the other hand the reaction with acetic acid went substantially to completion when the reactants were treated with sufficient boron fluoride in the absence of a solvent.

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Determination of Fluorine in Organic Compounds

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The study of the chemistry of fluorine, beginning with the early research of Moissan and continuing with the brilliant investigations of Otto Ruff, has attracted an ever growing number of chemists. Elementary fluorine is one of the most active and vigorous substances known to man. However, in spite of its great activity, fluorine can form compounds of extraordinary stability when it is linked with carbon, particularly when more than one fluorine atom is attached to a single carbon atom. Such substances resist decomposition by almost all of the ordinary chemical reagents. The great stability of these fluorine compounds has resulted in their use as refrigerant fluids in certain popular brands of refrigerators, and in their being patented for use as fire extinguishers, insecticides, moth-repellants and pharmaceuticals. Of great interest to scientists is the fact that these compounds are non-toxic to human beings, since they are not decomposed in the lungs when inhaled. Accordingly, their use involves no health hazard, which is especially important in chemicals used in the home. Their stability suggests many more uses for these materials, one of the possible applications being as a general anesthetic.

At the present time, research in fluorine chemistry is being carried on in many university and industrial laboratories, particularly the study of the preparation, properties, and uses of organic compounds containing fluorine. The increasing research on these compounds and their increasingly widespread industrial application has called attention to the desirability of simple methods for determining fluorine. The lack of an entirely adequate analytical method often presents a serious obstacle to research. The unsatisfactory nature of the methods heretofore used in the analysis of these stable compounds is illustrated by the fact that one method which used a complicated apparatus took four and a half hours to decompose a single sample. Other investigators noted that it took a week of heating at a high temperature to decompose some of these fluorine compounds so that they could be analyzed. A recent statement by Henne, Whaley, and Stevenson (**26**), in an article dealing with the preparation of organic fluorides, will illustrate this point: "Fluorine analyses, which are difficult and tedious, were performed at crucial points only. In general, the analytical results have a tendency to be slightly low, and this is attributed to the great difficulty of obtaining a complete decomposition of these extremely stable compounds."

The determination of halogen, including fluorine, in organic compounds consists of two principal steps: (1) decomposition of the sample to yield ionizable halogen, and (2) determination of the halide ion. Several satisfactory procedures exist for the decomposition of organic compounds containing halogen other than fluorine, including the Carius method of heating with nitric acid in a closed tube, oxidation by sodium peroxide in a Parr bomb, combustion in oxygen, or hydrogenation in the presence of a suitable catalyst. Each of these decomposition methods

has its advantages and its limitations. After decomposition of the chloro, bromo, or iodo compound, various standard methods provide for the separation and determination of the halide ion.

Difficulties are introduced in the analysis of aromatic fluorine compounds or highly fluorinated aliphatic compounds because of the stability of the carbon to fluorine bond. Meyer states (33) that the other halogens in halofluoro compounds can be determined by the Carius method or by lime fusion in glass without splitting out the fluorine. The presence of fluorine also may increase the difficulty of determining chlorine in chlorofluoro compounds. Henne and Renoll (24) state that the chlorine in certain chlorofluoropropanes could be determined only by the Carius method, which required a whole week of continuous heating at 250° C. to 300° C. to yield quantitative results. The Carius method, even if sufficiently drastic to decompose fluoro compounds, is unsatisfactory because the resulting hydrogen fluoride or hydrofluoric acid attacks the glass of the reaction tube.

The methods at present described in the literature, with few exceptions, either do not work for the more stable compounds or are described in insufficient detail and without sufficient experimental verification to permit their use. Most of the fluorine compounds for which analyses are reported are of comparatively low fluorine content, commonly having only a single fluorine atom in a molecule of high molecular weight. This choice of compounds makes the methods appear better than they actually are for two reasons: (1) a relatively large error on the basis of fluorine present appears as a small percentage error; and (2) applicability of the method to the more stable compounds containing two or three fluorine atoms on a single carbon atom is not tested.

Since the standard texts and references on organic analysis fail in most cases even to mention the topic, it is worth while to summarize the methods which have been proposed in the literature for the decomposition of organic fluoro compounds and the recovery of fluoride ion in a determinable form. Meyer (33) and Bockemüller (4, 5) give the most extensive discussions of the topic but the principle of the methods described is not clearly indicated nor is the method of determining fluoride ion shown; moreover, the treatment is incomplete and non-critical. Table I classifies the methods which have been suggested in the literature, and which are discussed in the following paragraphs. This classification is based upon the recent one of Elving and Ligett (14) which did not, however, describe the methods mentioned nor indicate the applicability of the various procedures.

TABLE I.—Decomposition of Organic Compounds Containing Fluorine

I. Oxidation Methods
   A. Combustion in oxygen (4, 31, 36, 38)
   B. Fusion with sodium peroxide (13, 19, 28, 39, 46)
   C. Alkaline oxidation (3)
II. Reduction Methods
   A. Combustion in hydrogen (8, 50, 51)
   B. Treatment with sodium in liquid ammonia (18, 52)
   C. Treatment with alkali metal in organic solvent (53, 54)
   D. Alkali metal fusion (1, 14, 29, 40, 41, 42, 43, 47)

III. Methods Involving Alkaline Fusion
  A. Fusion with calcium oxide (**2, 11, 12, 15, 25, 30, 34, 44, 45, 48**)
  B. Fusion with sodium carbonate or hydroxide (**6, 16**)
IV. Methods Involving Reaction with Silicon Dioxide
  A. Corrosive action on glass (**7, 22, 37**)
  B. Combustion over silicon dioxide using oxygen and hydrogen (**10, 23, 24, 27**)
V. Hydrolytic Methods (**21, 32, 35, 49**)

Oxidation Methods. The fluorine in methyl and ethyl fluorides was determined by Moissan (**36**) by combustion in a stream of oxygen in a copper tube containing a mixture of 80 per cent cupric oxide and 20 per cent lead monoxide. Bockemüller (**4**) burned samples of organic fluorides mixed with calcium carbonate in a platinum boat in a platinum tube; the fluorine was converted into calcium fluoride. The results for five compounds were good to ± 0.3 absolute per cent of fluorine present. It has been suggested (**31**) that the fluorine in gaseous organic fluorides be determined by burning the compound in oxygen on a hot platinum wire; the hydrofluoric acid formed is absorbed in an excess of standard alkali solution. Paterno (**38**) was able to determine fluorine by combustion under 25 atmospheres pressure in a calorimetric bomb containing potassium iodide and iodate, iodine equivalent to the fluorine was liberated and determined by titration with standard thiosulfate solution.

The determination of fluorine by oxidation of the organic fluoride with sodium peroxide in a Parr bomb seems to be successful with many compounds (**13, 19, 39**). The filling commonly used in the bomb consists of 0.5 gram of sample (not over 0.1 gram fluorine), 0.5 gram of sugar or starch, and 14 grams of sodium peroxide. Shoesmith, Sosson, and Slater (**46**) found that certain fluoro compounds explode spontaneously when mixed with the peroxide in an open vessel. Küster and Neunhoffer (**28**) claimed to be able to decompose organic fluorides by ignition in a nickel crucible with calcium peroxide or with a mixture of sodium carbonate and sodium peroxide.

Blum and Vaubel (**3**) were able to determine the fluorine content of fluorine derivatives of proteins by fusion with sodium hydroxide and potassium nitrate in a nickel dish and precipitation of barium fluoride along wth barium sulfate from the resulting extract.

Reduction Methods. The reduction methods for converting fluorine in organic compounds to fluoride ion use either hydrogen gas or free alkali metal. Cadenbach (**8**) suggested vaporizing the compound in a stream of hydrogen and burning the resulting mixture. Tetrafluoromethane had been detected by burning the suspected gas with hydrogen and noting the etching action of the flame (**50**). Treadwell and Zurcher (**51**) determined the fluorine and chlorine in three methane derivatives and one benzene derivative by burning the sample with hydrogen and a little air in a narrow platinum capillary and analyzing the resulting condensate for hydrofluoric and hydrochloric acids.

In 1931, Vaughan and Nieuwland (**52**) reported that fluoride ion could be recovered from organic fluorides by treatment of the liquid ammonia solution of the compound with metallic sodium. Results were

reported for four aromatic and one aliphatic compound. This method was also used by Govaert (18). Earlier, the presence of fluorine in 2-fluoro-6-nitrobenzoic acid had been shown by fusion with sodium and evolution of hydrofluoric acid from the resulting properly prepared residue (29). Ruff and coworkers (41, 42, 43) reported decomposing fluoromethane, fluoroform, and trifluoronitromethane, allowing the gases to stream into an evacuated quartz tube containing heated sodium in an iron boat. Complete destruction was apparently not secured even after repeated passage over the hot sodium metal and the amount of residual gas had to be determined. Simons and Block (47) were able to decompose fluorocarbons by an analogous technic with fairly good results. Wallach and Heusler (53) described a procedure for determining the fluorine in fluorobenzene which consists of keeping at 100° C. for several days a sealed tube containing equal volumes of the compound and of dry benzene, and sodium wire. Whearty (54) refluxed alcoholic solutions of fluorinated chlorobenzenes with metallic potassium and determined the fluoride ion formed by precipitation as calcium fluoride. Unfortunately, the results reported for fluorine fitted a probable formula in only one of the three analyses reported. Piccard and Buffat (40) analyzed fluorobenzene for fluorine by heating the compound to 400° C. with metallic potassium in an evacuated tube; the fluoride ion formed was determined by conductometric titration with calcium chloride. The results on three samples of fluorobenzene were ± 0.4 absolute per cent of the correct value. Potassium fusion has been used to detect the presence of fluorine in aromatic compounds (1).

The most thorough investigation of the reduction technic for the determination of fluorine in organic compounds was made by Elving and Ligett (14). The procedure which they developed depends upon decomposition of the compound by heating with sodium or potassium metal in an evacuated sealed glass tube at a moderately elevated temperature, i.e., 350° C. to 450° C., and determination of the resulting alkali fluoride by standard methods. The most applicable procedure for the latter seems to be precipitation of the fluoride ion as lead chlorofluoride and determination of the fluoride content of the precipitate by titration with standard silver nitrate solution (17, 20), using Volhard's method with the addition of nitrobenzene to avoid the necessity of filtering the precipitated silver chloride (9). The same technic serves for the analysis of chloro, bromo, and iodo compounds and has several advantages over the procedures commonly employed in these determinations. Analytical results were presented for twenty-four organic halogen compounds, including samples which were in the gaseous, liquid, or solid state, and which represented examples from the aliphatic, aromatic, alicyclic and heterocyclic series. Compounds with fluorine content as high as 60 per cent and two or three fluorine atoms on the same carbon atom were successfully analyzed. The procedure permitted the simultaneous determination of chlorine and fluorine in chlorofluoro organic compounds.

Since the paper describing this procedure was published, hundreds of organic halogen compounds, a majority of which contained fluorine, have been successfully analyzed by this technic. Other analysts have

also found the method applicable in analyzing organic fluorides which resisted decomposition by other means.

Methods Involving Alkaline Fusion. Several investigators have endeavored to apply the Liebig lime fusion method to organic fluorine-containing compounds. Attempts to carry out the fusion in glass resulted in the formation of some silicon tetrafluoride and in partial loss of sample (45). The use of a platinum tube improved the results but the latter were still in error by one or more absolute per cent (2, 11, 12). Meyer and Hub (34) asserted that to remove fluorine linked to an aromatic nucleus it is necessary to decompose the compound at 1000° C., which they did by heating the sample mixed with calcium oxide in an open nickel tube to yellow heat for two hours. The results on o-fluorobenzoic acid and o-fluorobenzamide were appreciably low. Better results were reported (15, 48) in analyzing the three fluorobenzoic acids and analogous fluorine compounds by this method. Ruff and Keim (44) found the correct fluorine to chlorine ratio on passing trichlorofluoromethane mixed with steam and nitrogen over hot calcium oxide in a platinum tube. Henne and Renoll (25) analyzed chlorofluoropropanes by decomposition over red hot calcium oxide in a small steel bomb. Unfortunately, no experimental details were given except the chlorine to fluorine ratios found, the accuracy being $\pm$ 0.05 for calculated ratios of 0.75 to 1.67. In an article by MacNevin and Baxley (30) applying the method of Henne and Renoll to the determination of chlorine in organic compounds, no mention is made concerning the details of the fluorine determination. Brauns (6) reported that fluoroacetyl sugars are decomposed by careful ignition with sodium carbonate, while Freudenberg and coworkers (16) were able to decompose ethyl phenylfluoroacetate by prolonged fusion with sodium hydroxide.

Methods Involving Reaction with Silicon Dioxide. The ready formation and volatility of silicon tetrafluoride under suitable conditions has been utilized in several methods proposed for the determination of fluorine in organic compounds. Several procedures have been used to determine the amount of fluorine from the empirically calibrated loss in weight of a glass plate exposed to the hydrofluoric acid formed when the compound is suitably treated with sulfuric acid, or by the similar loss in the glass vessel in which the reaction occurs (22, 37). In the most recent procedure (7) of this type, the sample is treated with potassium nitrate and sulfuric acid in a Pyrex flask, 1 mg. loss in the weight of the flask corresponding to 1.2 mg. of fluorine. The procedure requires about 4 hours. Hubbard and Henne (27) described a method for the simultaneous determination of chlorine and fluorine in aliphatic compounds which consisted of passing a measured amount of the gaseous or vaporized compound mixed with air or oxygen through a quartz tube heated to 900°C. and packed with crushed silica. The tube is then swept successively with oxygen, nitrogen, hydrogen (to remove absorbed silicon fluoride and to reduce silicon oxyfluoride), and nitrogen. The exit gases are passed through an absorbent solution containing sodium hydroxide and hydrogen peroxide, and the fluoride and chloride formed

are determined in separate portions of the solution. In a later paper, Henne and Renoll (24) mentioned that only the gaseous and highly volatile chlorofluoropropanes could be analyzed by decomposition over white hot silica. Calfee, Bigelow and coworkers (10) described a procedure based on Hubbard and Henne's method; a single combustion took 4.5 hours, exclusive of time needed to prepare and weigh the sample and to determine the halides in the absorbent solution. These workers reported the results for two methane and three ethane chlorofluoro derivatives. In 1938, a patent (23) was issued to Henne for detecting volatile organic fluorine derivatives in air, which was based on bringing the suspected air into contact with incandescent silica and passing the resulting gas into contact with ammonia to form a white cloud or precipitate.

Hydrolytic Methods. The stability of the carbon to fluorine bond is lessened, and the fluorine can be removed by hydrolysis, if oxygen is linked to the carbon in a carbonyl linkage as in acid fluorides. Helferich and coworkers (21) reported that d-glucosyl fluoride would surrender all its fluorine on ten minutes heating in acid solution. They also reported successful results on using the lime fusion method on this compound. Acetyl fluoride was decomposed by heating with an aqueous solution of calcium chloride (32), and Swarts (49) asserted that fluorine in the side chain of aromatic compounds could be removed by heating to 200°C. with concentrated sulfuric acid or by heating to 150°C. with water in a sealed tube. Moissan (35) found that the fluorine in alkyl fluorides is converted to silicon tetrafluoride on standing for seven or eight days with sulfuric acid in a buret over mercury.

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Relative Electronegativity,[1]

III. An Empirical Rule

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It has been suggested that the student of organic chemistry should learn all the theories of the science and that he should be able to apply them advantageously in the prediction of reactions and the interpretation of data, but that he should never succumb to belief in these fantasies.([1]) Be that as it may, the value of any theory is a direct function of its usefulness. No theory is accepted until it can be shown that it satisfactorily explains a number of phenomena, and no theory survives after it is shown that these phenomena can be explained on a much simpler basis. It is on the basis of utility alone, the validity of the postulate having been checked against over two hundred fifty cases, that the following empirical rule is offered as an aid in the prediction of organic reactions and the interpretation of experimental data.

By postulating that both the nature and relative positions of the atoms in an organic molecule determine the distribution of the electrons; it becomes possible to predict, by the proper assignment of electrostatic values, the relative electronegativity of each constituent carbon atom and the composite effect of such a distribution of the electrons on the course of a reaction.

In setting up the electronegativity map (Fig. I), the predicted bond energies for a number of simple bonds have been subtracted from their corresponding experimentally determined values to give a numerical quantity which has been labeled *delta* (Table I). Pauling attributes the existence of these *delta* values, that is, the difference between the actual and the predicted bond energies, to the ionic character of the bond. The square root of these *delta* values, expressed in volt electrons, accordingly, is then taken as the difference in electronegativities of the respective elements.([2])

This concept permits a quantitative evaluation of the qualitative values already afforded by the arrangement of the elements in the periodic table. Any element W that lies below or to the left of an element Y is electropositive with respect to Y. In general, the electronegative character of the elements increases as one passes from the lower left-hand corner of the periodic table toward the upper right-hand corner. The electronegativity map merely enables a quantitative interpretation of these relationships.([6])

If the organic molecule is regarded as a composite of atoms and electrical forces, each of the atoms must be assigned its electrostatic value. These electrostatic values may be determined conveniently by an

[1] Paper I. A Consideration of the Concepts of Relative Electronegativity, Proc. Ind. Acad. Sci., **50**:94 (1941), II. The Historical Development of the Concepts, Proc. Ind. Acad. Sci., **51**:167 (1942).

interpretation of the data given in the electronegativity map.[2](6) From this map it is seen that the hydrogen atom is placed at 2.1, the carbon, sulfur and iodine atoms at 2.5, the bromine atom at 2.8, the nitrogen and chlorine atoms at 3.0, and the oxygen at 3.5. Since most of the substituent groups on a carbon nucleus are normally hydrogen atoms, it seems advisable to make unity represent the difference between the relative electronegativities of the hydrogen atom at 2.1 and the carbon atom at 2.5. If this difference of 0.4 is taken to represent a unit electrostatic value, then the electrostatic value of the other atoms to be considered may be determined by multiplying the difference shown on the map, between their position and that of the carbon atom, by the factor 2.5. The electrostatic value of the bromine atom, for example, is calculated as follows:

$$2.8 - 2.5 = 0.3, \text{ then } 0.3 \times 2.5 = 0.75.$$

In each of these two cases the sign is minus with respect to the carbon atom. The electrostatic values for the other atoms are calculated in an analogous manner and found to be as given in Table II.

TABLE I. Setting up the Electronegativity Map
Energies of Single Bonds

C – C, bond..	58.6 Kg. calories per mole by experimental determination,
Cl–Cl, bond..	57.8 Kg. calories per mole by experimental determination,
	2)116.4
C –Cl, bond..	58.2 Kg. calories per mole, calculated value, but
C –Cl, bond..	66.5 Kg. calories per mole by experimental determination.

Therefore, *delta* is 8.3 Kg. calories per mole, which value is interpreted to be a direct measure of the ionic character of the carbon-chlorine bond.

By determining a number of *delta* values, extracting the square root and expressing the result in volt electrons, Pauling has developed a quantitative periodic table namely, The Electronegativity Map.

TABLE II. Electrostatic Values,[3] with Hydrogen at 1

Element considered	H	C	Br	Cl	N	O	:0
R. E. Vote, H-atom at 1	+1	0	—0.75	—1.25	—1.25	—2.5	—5

If the electronegativity map and this interpretation can be accepted as being approximately correct, it becomes necessary in the application of this new empirical rule to be guided by two postulates, namely, that:

[2] For an abridged form of the Pauling Electronegativity Map see the first paper of this series. Proc. Ind. Acad. Sci. **50**:97. 1941.

[3] The "electrostatic value" is selected as a convenient unit for these comparisons. These units are obtained by multiplying the net difference between the atom concerned and the carbon atom, on the Electronegativity May, by 2.5 so as to give unity for the hydrogen atom. The doubly-bonded oxygen atom is assigned a value of 5.0 (2 x 2.5), which value, presumably, is much too large.

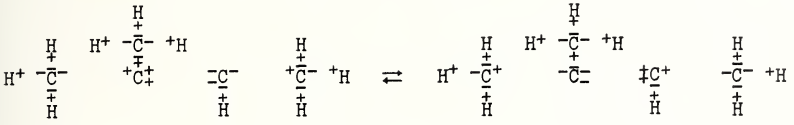
1. The distribution of the electrons in a given molecule is a function of the nature and relative positions of all of the substituent groups of a carbon chain or ring or nucleus, and

2. The properties of organic molecules suggest that the valence electrons *tend to cluster* about alternate carbon atoms, in a chain or ring, so as to produce an alternate polarity effect.

Addition to Olefin Bonds

The usefulness of the rule in a *qualitative* prediction of addition to an olefin bond may be illustrated by the reaction of hypochlorous acid with 2-methyl-2-butene, which has been studied by Detoeuf, and by the addition of iodine chloride to propene, which has been studied by Michael and by Ingold and Smith.

In setting up the electrostatic formula for 2-methyl-2-butene, the application of postulates 1 and 2 seems to suggest formulas A and B as representing *the two extremes of a type* of a resonating system.



Formula A Formula B

By inspection it may be seen that seven of the electropositive hydrogen atoms in Formula A are bonded to carbon atoms which tend to be completely electronegative, whereas only three electropositive hydrogen atoms are bonded to a carbon atom which bears one or more positive charges and tends to be electropositive. In Formula B, however, only three electropositive hydrogen atoms are bonded to carbon atoms which tend to be slightly electropositive. The ratio of the electrostatic values, therefore, of all of the substituent hydrogen atoms is seven to three (7/3) in favor of Formula A. For convenience, this ratio may be designated as the relative electronegativity (or R. E.) ratio.

If Formula A does represent the electronic configuration of 2-methyl-2-butene, the addition of hypochlorous acid should proceed according to the equation:

$$(CH_3)_2C^+{:}{-}CH.CH_3 + HO^-.{}^+Cl, \text{ aq.} \rightarrow (CH_3)_2C^+(-OH).(Cl^+)^-CH.CH_3,$$

but if a more correct picture of the electronic structure of 2-methyl-2-butene is presented by a type of resonance between Formula A and Formula B, and if Formula A is the more correct representation for about 70% of the time and Formula B for only about 30% of the time, the reaction should be formulated as:

$$(CH_3)_2C^+{:}{-}CH.CH_3 + HO^-.{}^+Cl, \text{aq.} \rightarrow (CH_3)_2C{\div}(-..OH).(Cl^+)^-CH.CH_3,$$

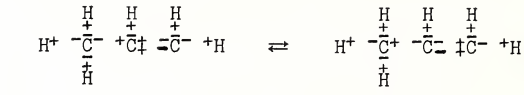
70% yield and

$$(CH_3)_2C^-{:}{+}CH.CH_3 + HO^-.{}^+Cl, \text{ aq.} \rightarrow (CH_3)_2C^-(^+Cl).(HO^-)^+CH.CH_3$$

30% yield.

It is of more than passing interest that Detoeuf(3) studied this reaction both qualitatively and quantitatively, and that he reports 70% of the isomer corresponding to that predicted from Formula A and 30% of the isomer corresponding to that predicted from Formula B.

Propylene may be formulated in terms of these postulates as:



Formula C Formula D

By inspection it is seen that the R.E. ratio for Formula C is 5/1 and that for Formula D is 1/5. If propylene is approximately represented by this type of a resonating system, the addition products should be about 83% of the type predicted from Formula C and only 17% of that predicted from Formula D. Michael,(5) as early as 1892, studied quantitatively the addition of iodine chloride to propylene and obtained the results indicated by the equations:

$CH_3^- {}^+HC^+ {}^-CH_2 + I^+ {}^-Cl \longrightarrow CH_3.CHCl.CH_2.I$, 75% yield, and

$CH_3^+ {}^-HC^- {}^+CH_2 + I^+ {}^-Cl \longrightarrow CH_3CHI.CH_2Cl$ 25% yield.

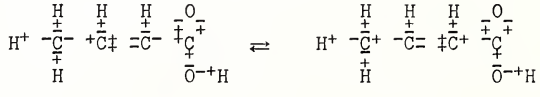
In 1931, Ingold and Smith(4) made a quantitative study of this same addition reaction and reported values of 69% and 31% for the respective isomeric products.

Similarly, Detoeuf(3) studied the addition of hypochlorous acid to 2-hexene and reported yields of 60% of 2-chloro-3-hexanol, whereas relative electronegativity indicates a 50% yield of this isomer.

Over two hundred fifty specific cases of addition have been tabulated and checked qualitatively against this *new empirical rule* with a validity exceeding 95%.

Addition to Unsaturated Acids and Related Compounds

The application of the rule to the addition reactions of the *alpha-beta* unsaturated acids and related compounds may be illustrated by reference to 2-butenoic acid, which may be formulated as:



Formula E Formula F

If only atoms bonded *directly* to the carbon skeleton are considered, the R.E. ratio is seen to be 11.5/1 in favor of Formula E. Addition reactions should proceed, therefore, so as to give about 92% of the one as compared to 8% of the other isomeric addition product. This particular reaction was studied quantitatively by Ingold and Smith(4) in 1931 who obtained the results indicated by the equations:

$CH_3^- \ ^+HC^+ \ ^-CH^+ \ ^-CO_2H + I^+ \ ^-Cl \rightarrow CH_3.CHCl.CHI.CO_2H$, 92% yield and

$CH_3^+ \ ^-HC^- \ ^+CH^+ \ ^-CO_2H + I^- \ ^-Cl \rightarrow CH_3.CHCl.CHI.CO_2H$, 8 % yield.

Reactions of this type involving H.X are usually interpreted by 1, 4— addition, but it must be obvious that iodine chloride cannot add to 2-butenoic acid by any such mechanism. All the additions of H.OX compounds to the *alpha-beta* unsaturated acids are, moreover, in qualitative agreement with this empirical rule. Another interesting case is that of the addition reactions of the acetal of propynal (7) as in the equation:

$$HC\ddagger \ \bar{=}C^- \ ^+CH(O\cdot Et)_2 + EtO\cdot Na/H_2O \rightarrow EtO\cdot HC\ddagger =CH^- \ ^+CH(O\cdot Et)_2 + NaOH, \text{ then}$$

$$EtO\cdot HC\ddagger =CH^- \ ^+CH(O\cdot Et)_2 + H_2O \rightarrow EtO\cdot HC^+(^-OH)\cdot(H^+)\text{-}CH^-\cdot \ ^+CH(O\cdot Et)_2$$

Considering only the atoms attached *directly* to the carbon nucleus, the R. E. ratio of the acetal of propynal is 5/2.

A number of specific cases of 1, 4— addition have been tabulated and all cases thus far observed are in qualitative agreement with the empirical rule stated at the beginning of this paper.

General Applicability of the Rule

Cases selected at random from the literature indicate that the rule applies to: (1) all types of addition reactions, (2) condensations, (3) decarboxylations, (4) double decompositions, (5) esterification, (6) rate of ionization, (7) polymerizations, (8) vinylogy, (9) lactol and lactone formation, (10) loss of H.Y from certain types of compounds, (11) rate of oxidation, (12) relative stability, (13) molecular rearrangements, and (14) organic reactions in general.

This empirical rule is not a sure guide, but it does appear to have a high degree of validity. On its usefulness alone, it is offered here as a valuable postulate.

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1. Adkins, Homer, local citation.
2. Degering et al, An Outline of Organic Chemistry, p. 17 (1937, 1939).
3. Detoeuf, Bull. soc. chim., **31**:169, 176 (1922).
4. Ingold and Smith, J. Chem. Soc., 2742 (1931).
5. Michael, J. prakt. Chem., **46**:205 (1892).
6. Pauling, Linus, J. Am. Chem. Soc., **54**:3570 (1932); Degering et al, An Outline of Organic Chemistry, p. 17 (1937, 1939).
7. Whitmore, Frank C., Organic Chemistry, p. 425 (1938).

Geology and Geography

Chairman: G. T. WICKWIRE, Hanover College

Professor W. T. Buckley, Indiana University, was elected chairman of the section for 1943.

ABSTRACTS

Civilian defense geography of Valparaiso, Indiana. N. S. AMSTUTZ and A. H. MEYER, Valparaiso University.—The organization of the civilian defense program for the various urban communities in the United States creates a novel demand for geographic mapping of the defense type. One of the principal responsibilities is the preparation of zone and sector maps on which are placed various conventional symbols. In accordance with these principles a large map of the entire city and twenty-one sector maps have been prepared for the city of Valparaiso.

Geographical regionalism of world problems. A. H. MEYER, Valparaiso University.—America's total defense participation in the present global war has revealed the need for new type courses in high school and college geography. Guiding principles for the development of future courses are presented.

Indiana's petroleum supply. WALLACE T. BUCKLEY, Indiana University.—A study was presented of Indiana's requirements for petroleum products, particularly gasoline, in relation to a) production of petroleum in Indiana and adjacent states; b) crude oil and gasoline pipe lines; c) location and capacity of oil refineries.

Secondary air flows of the northern hemisphere. A. V. LOTT, Sellersburg.—The primary movements of the basic wind system tend to produce two secondary air flows from each unit of circulation. A working knowledge of the formation and movements of these air masses is expected to be of great value in long range weather forecasting.

Nature's explanation of the climates of yesterday. A. V. LOTT, Sellersburg.—The outstanding feature of the climates of today is the warm dry period that now prevails near latitudes thirty degrees north and south of the equator. A theory is presented to relate present weather phenomena to climatic changes that have occurred in past geologic ages.

Important minerals in the sands of Florida. WILLARD B. PHELPS, DePauw University.—The beach sands of Florida contain the heavy minerals, ilmenite, rutile, and zircon, which are important to our war industries at the present time. This paper discussed the natural concentrations of heavy minerals, their areal extent and depth, and their geographic and geologic location in the state of Florida. Mineralogical analyses of the important districts show definite promise.

An unusual specimen of "Pencil" Marcasite. ERNEST RICE SMITH, DePauw University.—A considerable specimen of "pencil" marcasite was uncovered this summer in the Greencastle quarry of the Midwest Rock Products Corporation and called to the attention of the writer by Mr. R. R. Foley, Superintendent of the quarry. Its geological location, characteristics, and possible origin were discussed.

A St. Louis-Lower-Chester Section in Greencastle Township, Putnam County, Indiana. ERNEST RICE SMITH and RICHARD A. SCOTT, DePauw University.—Well logs in Section 29, Greencastle Township, correlate with the known St. Louis-Beaver-Bend section in the deep quarry at the Indiana State Penal Farm west of Putnamville and lower Chester formation through the sample in the well-known Reelsville Hill. This extends the known areal distribution of the lower Chester eight miles north-east of Reelsville.

Looking Toward a Quantitative Geology

GRANT T. WICKWIRE, Hanover College

For a good many years geologists have been assuming that rock A was resistant and that strata B was erodable. Such an assumption is probably not open to serious question. But we have never been able to say with any certainty *how much* more erodable strata B was than A. This desire for quantitative measures in geology, particularly in relation to erosion, is no new thing. Indeed it seems to have been almost as old as the science itself.

Now desire is becoming a need. Erosion has ceased to be merely an academic study. It has become a threat to our welfare. No one can travel without seeing that fields are losing their fertility and many are turning into gullies. A quantitative geology that can be applied to the control of gullying seems to be developing. But a quantitative geology that is applicable to the morphology of streams in general is still in the distant future.

Purpose of this report. It is the purpose of this report first, to review the literature on the quantitative aspects of stream work as it has come to the attention of the writer; second, to attempt to outline the difficulties that confront the student attempting a quantitative geology, in so far as a review of he literature permits; and finally to suggest additional means of approach to the problem.

Previous Work

There have been two groups of workers that have attacked the problem of how much erosion water can do, the geologists and the hydraulic engineers. Studying their work one is inclined to paraphrase the late Peter Cunne's "Mr. Dooley" who, commenting on the care of the sick by Doctors and Christian Scientists remarked, "If the Doctors had a little more Christianity and the Christian Scientists had a little more science, t'would make no difference who you called, provided you had a good nurse." Similarly one wishes the geologists had a little more engineering and the engineers a little more geology.

Various Geologic Approaches

One approach to the problem of how much a stream erodes is continued observation over a period of years. Thus Dreyer and Davis[1] reported in the Proceedings of this Academy on the work done by a normal brook in thirteen years.

They listed the disappearance of islands, the cutting off of an oxbow, and lateral erosion, thus making "a broad flood channel". No estimates of the amount of material actually transported are offered.

[1] Dryer, Chas. R., and Davis, M. K. "The Work Done by a Normal Brook in Thirteen Years." Proc. Ind. Acad. Sci., **20**:147-152. 1910.

The Culbertsons[2] also offered a paper before this Academy that dealt with the retreat of Clifty Falls. Their studies take no account of various factors of stream flow; volume, velocity, etc., but show what has been done by a stream in cutting back a falls over a period of years.

Speaking of falls, none has been more intensively studied than Niagara. Camera lucida sketches were made as early as 1827 and surveys have been made repeatedly since 1842. Estimates based on this work give a present rate of recession of $\frac{7}{10}$ mile per year, "but involve uncertainties that make the figure unreliable."[3]

In this same category of what I term in my own mind the "historical approach", is an article by Ireland[4] in the Journal of Geology in which he describes how erosion over a period of 100 years developed a gully of truly stupendous proportions. But here, as in the work of the Culbertsons, hydraulic data is limited.

Quite a number of similar studies are found in the literature. They are open to the criticism that they do not consider the hydraulic factor in sufficient detail to offer a basis for generalization.

A different geologic approach is the consideration of deposition as a measurable factor. The work of Antevs[5] is a case in point.

If we accept the fundamental premise of the seasonal nature of banded clays we have a record of many centuries of deposition. Moreover, if later discoveries[6] are incorporated with Antevs' work the areal extent of such deposition can be determined. We are, however, strictly limited in even the inferences that may be drawn as to the nature of the streams that caused the deposits.

From the point of view of developing a quantitative study, the work of Brown[7] is of greater value. His "Studies of Reservoir Silting", while little more than a preliminary notice of what is to be done, suggest that when observations have been made over a period of years we may actually know how deposition occurs.

Silting study is a Soil Conservation Service project and hence under federal supervision. We can only hope that such a worthy work can be continued during and after these war years.

Silting has also been approached from another direction by Brown and others. Brown has reported on "Silt Measurements During a Potomac River Flood."[8] This brief note gives a definite estimate (7,200,000 cu. ft.

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[2] Culbertson, J. Archer. "Further Observations of the Erosion of Clifty and Butler Ravines, Jefferson County, Ind." Ind. Acad. Sci. Proc. **37**:117-120. 1927. This paper summarizes a previous paper by the author's father covering observations begun in 1897.

[3] Schuchert, C., and Dunbar, C. O. "Textbook of Geology, pt. 2 Historical Geology." John Wiley and Sons, 1941, p. 438.

[4] Ireland, H. A. "Lyell" Gulley, A Record of a Century of Erosion. Jour. Geol. **47**:47-63. 1939.

[5] Antevs, Ernst. "The Recession of the Last Ice Sheet in New England." Am. Geog. Soc. ser. No. 11, New York, 1922.

[6] Flint, R. F. Glacial Geology of Connecticut." Conn. Geol. and Nat. Hist. Survey, Bull. 47. 1929.

[7] Brown, Carl B. "Studies of Reservoir Silting." Soil Conservation **1**:1-5, 14. 1936.

[8] Brown, Carl B. "Silt Measurements During a Potomac River Flood." Soil Conservation **7**:14. 1936.

per hour) for the rivers silt bed. The author believes this to be low rather than an excessive estimate.

The most complete study of silting that has come to my attention is that of the New River Watershed.[9] There are four reservoirs on the New River, the oldest of which was 33.5 years at the time the study was made. These reservoirs have not retained all the sediment carried by the New River, but certainly during the earlier years they must have been very effective in settling the mechanical load of the river.

Be that as it may, the average annual accumulation per acre of drainage area is determined. The nature of the sediment is described as to size, color, and composition. The vegetable cover of the watershed is noted. Furthermore, though not considered by Brown and Barnes, hydraulic data are available for the river, as the U. S. G. S. maintains a gauging station at Ivanhoe on the New River. Reports from the station give a clear picture of amount, intensity and distribution of rainfall and flood waters. It would seem that here we have many of the variables measured and that a coherent picture of the rate and way of erosion can be determined. Such is the case as it applies to the New River. However, it is not yet possible to apply the results of these observations generally.

The Hydrodynamic Approach

Present day consideration of the way a stream carries debris as well as the amount carried is founded on the work of Gilbert.[10] He gave us the concept of suspended and tractional load, as well as the concept of competent slope and competent discharge. Turbulence as a means of lifting the suspended load of a stream was not recognized as such; though a result of turbulence—the rippling of any surface of discontinuity—was described as the "rhythmic forming of dunes."

Furthermore, a series of equations for capacity, that is the maximum load of a given kind of debris which a given stream can transport, in relation to slope (defined in per cent grade), discharge (cubic feet per second), and fineness (computed as a function of both the mean diameter of the particles and the number of particles in a unit volume of debris), is set forth. The equations all fall in the same form, that is $C = k(F\text{-}f)^n$, letting C equal capacity, F equal the factor in question (slope or discharge or fineness), f equal the competent factor, that is a limiting value below which movement does not occur. In any series of observations k, n are constants found empirically and varying widely. Thus in the slope formula, k constant, n varied from .93 to 2.37, "values being greater as discharges are smaller or debris coarser." Similarly in the discharge formula n varied from .81 to 1.24, "values being greater as slopes are smaller or the debris is coarser." In the fineness formula n varies from .50 to .62, "values being greater as slopes and discharges are smaller."

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[9] Brown, Carl B., and Barnes, F. F. "Reservoir Silting in the New River Watershed." Soil Conservation **2**:95, 106-107. 1936.

[10] Gilbert, G. K. "Transportation of Debris by Running Water." U. S. G. S. Prof. Paper 86. 1914.

It is this important parameter (n) that has been the stumbling block in any application of the formulae to natural streams and has been a challenge to all subsequent students.

Gilbert also finds that capacity varies as the 3.2 to 4th power of the mean velocity, values of the power "being greater as slope, discharge and fineness are less."

Of these later works which have come to my attention, that of Leighly presents most clearly the reasons for questioning the capacity-velocity relation of Gilbert. Leighly[11] shows by observation and equation that there are three parts in a stream. Region 1 is an axial region of maximum velocity and moderate turbulence, and contains only such silt as is diffused to it from adjacent regions; in other words low to moderate silt load. Part 2 consists of two flanking regions each side and below region 1. Here turbulence is high, velocity moderate, and suspended load greatest, the maximum load within this region being below and to each side of the axial region. Part 3 consists of two lateral regions lying beyond the flanking regions and impinging on the sides and bottom. The lateral region has low turbulence and low velocity. It receives suspended material from the flanking region but tends to deposit it. The flanking area is apparently one of high silt concentration and low velocity.

The theoretical and mathematical aspects of Leighly's paper are considered by O'Brien, whose findings tend to confirm Leighly's. O'Brien[12] is, however, careful to add that further observations are required to establish a sound basis for calculations.

Just how necessary such qualifications prove to be is brought out by a report of Love[13] on suspended matter in small streams. First of all, it appears that a few days of high water carry most of the load of a stream. Second, it appears that during one period of flood the West Fork of Deep River near High Point, N. C., showed a load of 100 tons per hour suspended matter at discharge rates of 470, 670, 900 sec. ft. Worse still, spring and fall high water on the same stream showed different loads at the same discharge rates. A falling stream characteristically showed a lighter load than a rising one at the same discharge rate. That is, a small stream is cleaned out by a vigorous flood. Less is then carried until a new supply of debris accumulates. The mathematical approach has to date ignored this fact, so far as I have been able to discover.

So much for hydrodynamics. Let us now look at the last and probably most expensive field of study of this problem of erosion, the use of scale models.

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[11] Leighly, John. "Turbulance and the Transportation of Rock Debris by Streams." Geog. Rev. **24**:453-464. July, 1934.

[12] O'Brien, M. P. "Notes on Transportation of Silt by Streams." Am. Geophys. Trans. **17**:431-436. 1936.

[13] Love, S. K. "Suspended Matter in Several Small Streams." Am. Geophys. Union Trans. **17**:447-452. 1936.

The Terrain Model Approach

The use of scale models[14] constructed of material taken from the area being studied, or of material believed to be erodable in some ratio to that of the area represented, seems to have been practiced extensively by the Germans. One meets numerous references to their findings in most theoretical reports. During the past decade the Corps of Engineers, U. S. Army, have constructed numerous models in connection with channel and silt control of the Mississippi and Columbia Rivers, as well as harbor works on our east and west coasts.

Reports on much of this work have not been made available to the public by the U. S. Engineers. Fortunately a report by Vogel[15] of the Waterways Experiment Station, Vicksburg, Miss., gives a clear picture of the set-up and working of these models. The models are made with considerable distortion of vertical to horizontal scale. In a model described, horizontal scale was 1/1000 while vertical was 1/125. Further, the erodable material composing the bed of the model is not necessarily the same as that of the stream being studied. Vogel further points out that if the exaggerated slopes of the distorted model are not sufficient to make streams flowing over the model assume the velocities desired, the model is further distorted by tilting the whole thing.

In defense of these models it can be said that these distortions are held in a logical mathematical relation and the relation of the force required to move one kind of material to that force required to move another is predetermined by flume observations.

So far as I can discover, no effort has been made to apply the specific studies of small areas of stream to the larger field of morphology of the river; and properly not, since it has always been a fallacy to argue from the particular to the general. The usefulness of the model lies in the fact that here we have a way of controlling the many variables in erosion, so that the effect of each may be determined separately, though the combined effect may not be—in fact is not—a simple summation.

The criticism of models as a means of learning about erosion seems to be chiefly that *runs* over the model are usually just long enough to determine whether or not a specific change in control works will produce the effect desired. They have been used, as some author puts it, as a way of solving the complex mathematical equations involved in the play of natural forces in an area. Is that a way of saying that the model is a means of taking care of the unknowns in the complex mathematical equations, without which the equations are unsolvable? It is the unknown factor, not the known, that prevents our progress towards a quantitative geology.

The Difficulties Involved

Laboratory Control. The laboratory study of stream erosion as exemplified in the bed-model just described is confined to study of limited areas and specific problems connected with stream control within

[14] The earliest use of hydraulic models seems to have been by Osborne Reynolds in 1885 for the development of regulating works along the Mersey.

[15] Vogel, Herbert D. "Movable Bed-Models." Am. Geophys. Union. Trans. **14**:509-512. 1933.

the limited area. It does not give an over-all picture. Indeed, findings in connection with a particular stretch of river are not applicable to another area of river even a short distance away, much less to rivers in general.

Factors Involved. Little is known of the factors involved in erosion. Nichols[16] considers that "The whole field of the hydraulics of erosion is practically untouched". In this he includes entrainment, bed load, suspended load, sorting and deposition. H. H. Bennett[17] comments even more strikingly on the variable when he says, "Not only are the interdependent processes of absorption, run-off, and erosion profoundly affected by slope, climate, soil, and cover of vegetation and vegetative litter, but by the condition of the surface soil resulting from various methods of utilization, and, subsequently, by the condition and character of the different sub-layers successively exposed by planation. These and other factors introduce . . . . an almost inconceivable number of highly pertinent variables."

It is the lack of knowledge of these variables that inhibits our progress toward a true understanding of the quantitative aspects of erosion. Nowhere can one find a comprehensive summary of the known factors. Data on run-off is assembled by one group, that on soil loss by another, while yet a third gathers information on the silting of reservoirs. Moreover, few if any of these studies are undertaken on a long period basis. Weather bureau studies are just beginning to bear fruit after 80 years of observation. And while one would not say that meteorology is less complex than geology, certaintly it is not more so.

Specifically, it seems to me that there are certain details of erosion that are especially lacking. For example, the relation of stream load to velocity is subject to much mathematical speculation by relatively little actual measurement of samples, due to the expense of analysis. The concept of the overloaded stream has been invoked to explain certain phenomena. Apparently we need the concept of an underloaded stream as well. Is this an explanation of the very swift, often crystal clear, mountain stream? If so, what does it mean to the overall picture of erosion? We are woefully lacking in knowledge of what part of the stream does the major part of the carrying of either suspended or traction load. In fact, are these separate or gradations of a single process?

It is perhaps presumptuous to attempt to enlarge on the variables involved in the erosion process beyond what has already been offered. Nevertheless I shall attempt to set before you a systematic arrangement of what is known.

A stream can do three things; corrode and corrade its bed, transport its load. These acts are in some mathematical relation to the stream's velocity. Though what that relation can be in view of the work of Love[18] is difficult to see.

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[16] Nichols, Mark L. "Research Problems in Conservation Engineering." Soil Conserv. **5**:183-185. 1940.

[17] Bennett, H. H. "Dynamic Action of Rains in Relation to Erosion—etc." Amer. Geophys. Union. Trans. **15**:474-488. 1934.

[18] Loc. cit. p. 6

Velocity varies in some relation to the slope, volume load, and bed form. Each of these in turn have variables that affect them, which we can briefly enumerate in outline and without discussion. Slope is not merely a matter of degrees inclination from the horizontal but involves also length, roughness, vegetation, and material (i.e., soil, gravel, rock, etc.). Volume depends on precipitation with intensity, total amount, seasonal distribution, state—i.e. snow or rain, and evaporation as factors. The effect of volume further depends on absorption by soil, by vegetation with its attendant litter, and slope. Finally volume is a relative term, dependent on cross-sectional shape and capacity of the bed. Load factors are debris fineness and available amount, turbulance—both self generating as evidenced by ripples, and that induced by bed irregularities—, depth of water, and volume. Bed-form factors are cross-sectional shape, roughness, sinuosity, and are related in turn to slope and volume and load. In each of these categories there may be additional unknown and known factors. But at least this outline serves as a guide and suggests the great complexity of the problem.

One need not consider that this problem of a quantitative geology is so complex as to be unsolvable. However it is doubtful whether an individual in a lifetime could assimilate all data now available. As a group project it would not present unsurmountable difficulties. Certain data are needed, particularly in relation to varying loads in the different parts of a single stream, as well as a continuous record of sediment transported past some point determined as average for the stream. This we can now consider.

A Means of Approach

The Geological Survey maintains a host of gauging stations recording the run-off of streams. At these stations are current meters which give us continuous records of stream flow past the point of observation. At some stations silt samples are collected at various times and analyzed. At a few stations aliquot samples of water are taken continuously and the silt load determined. This does not seem sound. The aliquot sample requires the drawing off of water from the side of a flume. It may or may not represent an average. The same is true of other sampling methods.

It is therefore suggested that a device be designed by which a continuous record of silt load may be recorded. Furthermore this device, like a current meter, should be designed to record at varying depths and distances from shore.

It is to be regretted that details of this device cannot be offered at this time, but war work and other demands upon the time of the laboratory that has agreed to assist in the design of the apparatus has delayed making it.

The St. Louis and Ste. Genevieve Limestones of Harrison County, Indiana

PRESTON MCGRAIN, Indiana University

Introduction

Purpose. The purpose of this paper is to present the results of a detailed study of the St. Louis and Ste. Genevieve limestones in the central and western portions of Harrison County, Indana. The very nature of the problem made it necessary to limit the area studied. References to other areas may be made for the purpose of emphasis or explanation.

Since little attention has been given to the detailed stratigraphy of these limestone formations an effort is made to afford a clearer and more definite understanding of them. More specifically it is presented to show the thickness of each formation, important lithologic and faunal characteristics, and persistent units which can be used as mappable horizons.

Location. Harrison County lies in the extreme south central portion of Indiana. It is bounded on the southeast, south, and southwest by the Ohio River, on the west by Big Blue River and Crawford County, on the north by Washington County, and on the east by Floyd County. The area under consideration in this paper contains approximately 250 square miles and comprises parts of congressional Townships 1 and 5 South, Range 2 East, Townships 1 and 6 South, Range 3 East, Townships 1 to 6 South, Range 4 East, and all of congressional Townships 2 to 5 South, Range 3 East. Corydon, the county seat, is located in the approximate geographic center of the county.

Indiana highways 33, 62, and 64 cross the area in an east-west direction, and Indiana highway 135 crosses it in a north-south direction. Numerous other roads of various degrees of improvement cross the area described. The Southern Railroad approximately parallels highway 64 in the north central part of the region. The L., N. A., and C Railroad, a branch line of the Southern Railroad, extends 8 miles from the main line to Corydon.

Physiography. Central Harrison County lies almost wholly within the karst Mitchell plain developed in the St. Louis and Ste. Genevieve limestones (Fig. 1). The more typical karst area is a plain with little local relief. This expansive karst plain is gently rolling to flat and is marked with innumerable sinkhole depressions. The topography produced by the deeply intrenched Ohio and Blue rivers, and Indian and Buck creeks which flow across the upland sinkhole plain provides the greatest relief. These main streams are practically without surface tributaries. Most of the drainage of the karst enters numerous sinkholes and passes

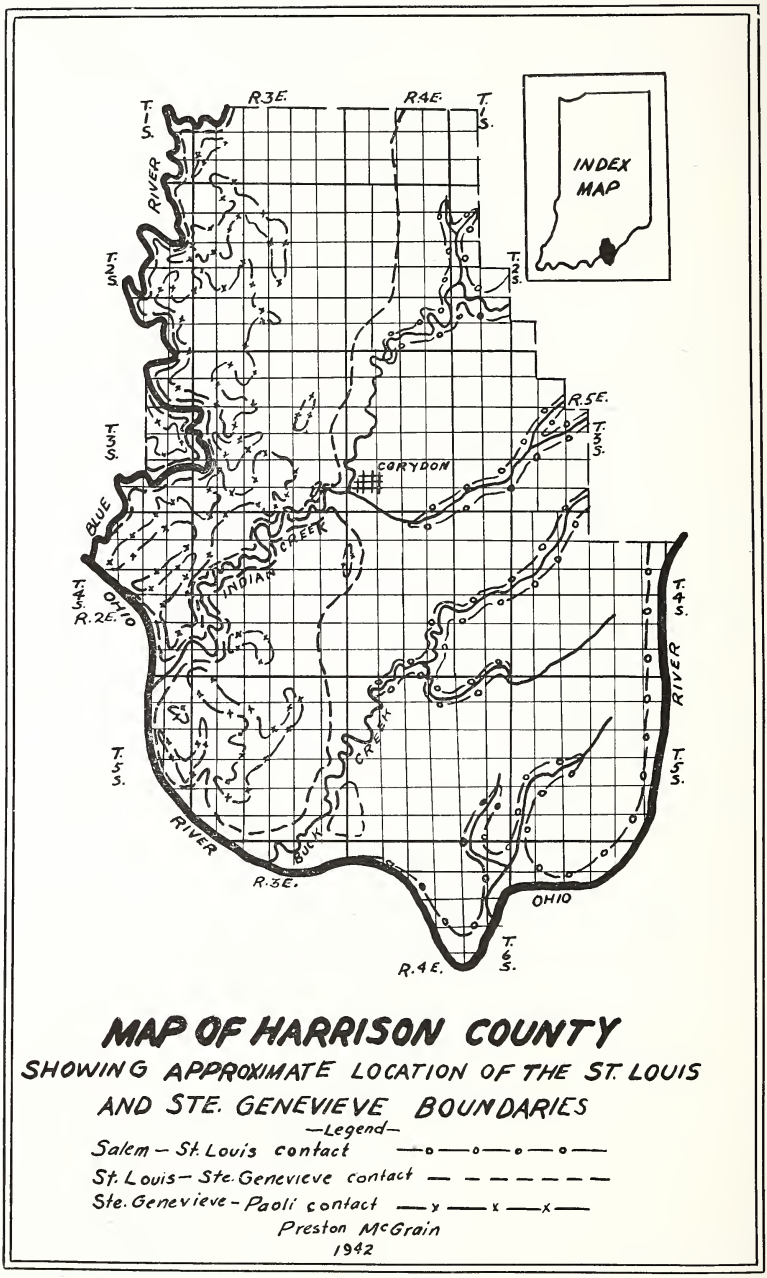
INDEX MAP
R.3E.
R.4E.
T. 1 S.
T. 2 S.
T. 3 S.
T. 4 S.
T. 5 S.
T. 6 S.
R.5E.
R.2E.
OHIO RIVER
BLUE RIVER
INDIAN CREEK
CORYDON
BUCK CREEK
MAP OF HARRISON COUNTY
SHOWING APPROXIMATE LOCATION OF THE ST. LOUIS AND STE. GENEVIEVE BOUNDARIES
—Legend—
Salem – St. Louis contact
St. Louis – Ste. Genevieve contact
Ste. Genevieve – Paoli contact
Preston McGrain
1942

Fig. 1.

through underground routes to the main streams. Evidences of underground drainage are the existence of many springs along the deeply set valleys and also the presence of many caverns. The Mitchell plain is essentially a regional slope which is inclined westward at the rate of approximately 20 feet per mile as compared with the bed rock itself which dips at the rate of 30 to 35 feet per mile to the west.

The western portion of Harrison County lies in the eastern edge of the Crawford Upland. Hills and ridges capped by sandstones of the Chester series rise 100 to 200 feet above the karsted limestone plain in the eastern portion of the area. The extreme western part of Harrison County exhibits topography typical of the Crawford Upland. The region is a well dissected upland of considerable relief. Many of the valleys in this hilly area are bottomed in the limestone and possess karst features. Malott (1939) called this type of valley *karst valley*. Numerous springs and caves are also found in this area. Harrison Spring (formerly called Wilson Spring), reported to be the largest spring in Indiana, issues from a deep pit in the St. Louis limestone in the NE quarter of Sec. 19, T. 3 S., R. 3 E.

Stratigraphy

Age and Nomenclature. Considerable difference of opinion has arisen regarding the age assignment of the Ste. Genevieve limestone. The age of the St. Louis and Ste. Genevieve has been set as Meramecian by Wilmarth (1928) although Ulrich (1904) included the Ste. Genevieve in the Chester group. In recent years voluminous literature has appeared on the correlations of the formations of the Chester group and classification of the Ste. Genevieve limestone in the Mississippi Valley region. There has been little question as to the age of the main body of the St. Louis limestone (Fig. 2).

The names Mitchell, St. Louis, Barren, Lithostrotion limestone, Cavernous limestone, Lawrence-Crawford (part), Concretionary limestone, Middle limestone (part), Paoli (in part), and Mammoth Cave formation have been applied to the St. Louis-Ste. Genevieve sequence in Indiana. Siebenthal (1897), believing that the limestones between the well known building stone (Salem) and the Chester clastics could not be correlated with the St. Louis limestone, as had been the case prior to this time, named the sequence Mitchell limestone from the town of Mitchell, Lawrence County, Indiana. The name Mitchell was used in this comprehensive sense for many years, chiefly because the series of limestone units are difficult to separate into mappable units. The feature that perhaps adds most to the difficulty is the fact that most of the St. Louis, Ste. Genevieve, and Paoli formations form a karst plain rather deeply buried in the residual clay. Ulrich (1911) correlated the Mitchell with both St. Louis and Ste. Genevieve. The name Paoli was first proposed by Elrod (1899) for the upper part of the limestone sequence which is now practically equivalent to the Ste. Genevieve and the lowest limestone member of the Chester. This name, however, has been restricted by Cumings (1922) for the extreme top of the Mitchell; it is the lowest member of the Chester series in Indiana and underlies the Mooretown sandstone. The present writer would follow the sugges-

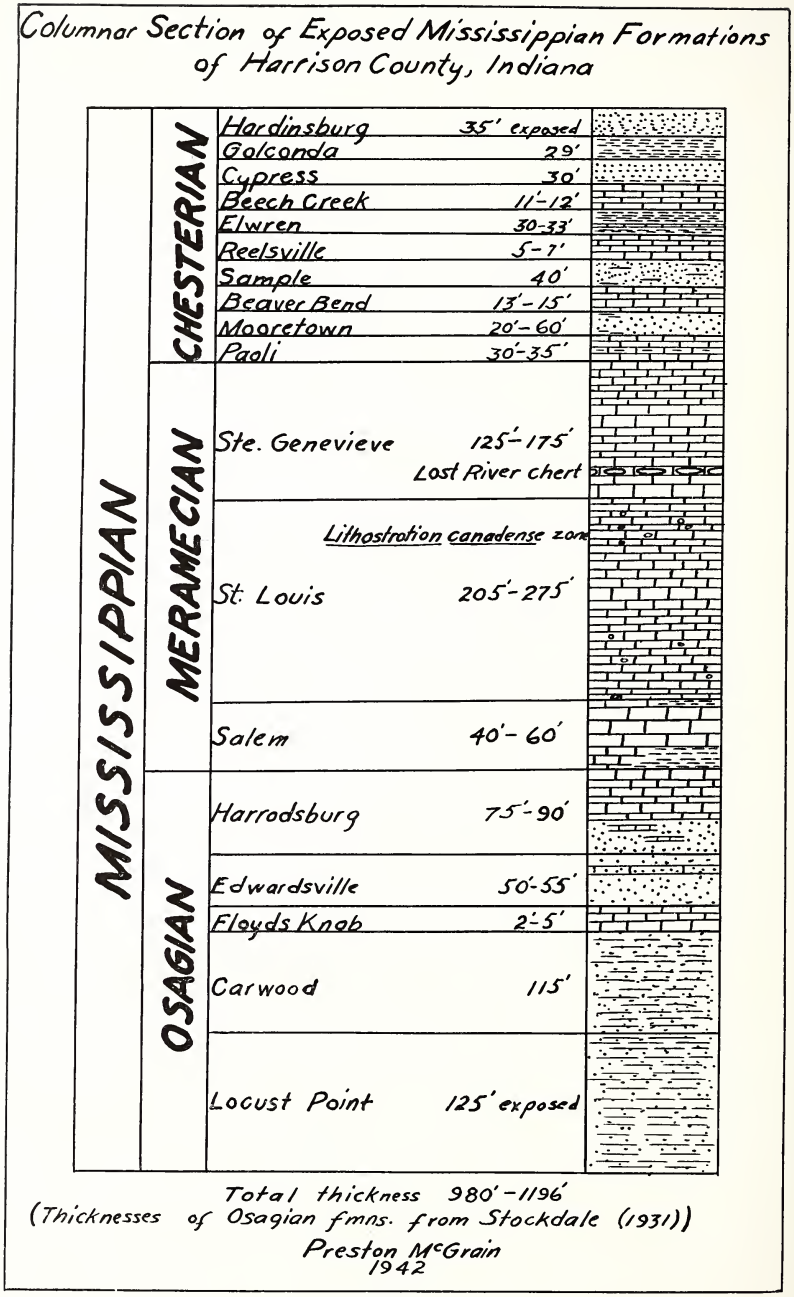
Columnar Section of Exposed Mississippian Formations of Harrison County, Indiana
MISSISSIPPIAN
CHESTERIAN
Hardinsburg 35' exposed
Golconda 29'
Cypress 30'
Beech Creek 11'-12'
Elwren 30-33'
Reelsville 5-7'
Sample 40'
Beaver Bend 13'-15'
Mooretown 20'-60'
Paoli 30'-35'
MERAMECIAN
Ste. Genevieve 125'-175'
Lost River chert
Lithostrotion canadense zone
St. Louis 205'-275'
Salem 40'-60'
OSAGIAN
Harrodsburg 75'-90'
Edwardsville 50'-55'
Floyds Knob 2'-5'
Carwood 115'
Locust Point 125' exposed
Total thickness 980'-1196'
(Thicknesses of Osagian fmns. from Stockdale (1931))
Preston McGrain
1942

Fig. 2.

tions of Butts (1918) and Cumings (1922) to discard the term Mitchell and return to the long established names St. Louis and Ste. Genevieve.

General Lithologic Characteristics of the St. Louis Limestone. *Nature of Sediments.*—The St. Louis in Harrison County is primarily a well jointed, thin-bedded limestone. One set of joints runs in a general north-south direction; the second set of joints, aligned approximately normal to the first, runs east and west. Both sets of joint planes are essentially vertical.

The St. Louis limestone ranges in texture from the extremely fine-grained lithographic stone which breaks with conchoidal fracture and shows no macroscopic grains to rather dense beds which have the particles plainly visible. The greater portion of the formation can be classed as medium to fine grained. A few of the strata are extremely crystalline; others show few traces of crystals; and the two extremes may occur in the same section. In some instances the beds contain many fossils, whereas in others no traces of organic remains are determinable. In general, however, macroscopically determinable organic matter constitutes only a small portion of the St. Louis.

Argillaceous material, though not abundant, is common in the St. Louis both as impurities in the limestone and as thin layers of blue, gray, or green shale between the strata, especially in the lower part.

Dolomite is also common in the St. Louis. Although none of the strata appears to be highly magnesian, local concentrations of dolomite in the form of druses are present near the top of the St. Louis in dolomitic limestone strata.

One of the most striking features about the St. Louis is the presence of great amounts of chert and flint scattered throughout the formation. The St. Louis chert is largely in the form of nodules but lenses and stringers are also present. At various horizons, especially near the top, there are local concentrations of nodules. The lower St. Louis is not characteristically as cherty as the middle and upper portions of the formation. On the weathered outcrop these nodules and lenses project beyond the limestone surface in irregular knobs and layers (Fig. 3).

Fig. 3. Concentration of chert in the upper St. Louis along highway 62, 5½ miles west of Corydon, Sec. 19, T. 3 S., R. 3 E.

Color of the Rocks.—The color of the St. Louis limestones on the fresh surface ranges from light to dark gray or nearly black, the greater portion of the formation being a medium gray color. The presence of magnesian or argillaceous material occasionally causes a deviation from the gray and the result is usually blue-gray, green-gray, brown-gray or tan.

Impurities in the form of iron compounds give yellow and red colors, and much of the St. Louis which is ordinarily gray on the fresh fracture becomes buff or reddish-brown on exposure, due to the oxidation of the ferrous iron which it contains.

Bedding.—The St. Louis can best be described as a thin-bedded limestone formation. Most of the strata range from a few inches to 2 or 3 feet in thickness. However, due to its hard, dense character it might appear massive on the outcrop. The strata, especially on the weathered outcrop, are usually marked by sharp bedding planes. Occasionally a well laminated bed is found but these are not common. The bedding planes are frequently in the form of stylolites. They are so numerous that this feature can be called an important characteristic of the St. Louis formation. In size they range from a fraction of an inch to several inches.

Several patterns of ripple marks have been observed in the upper half of the formation. Crossbedding is apparently absent in the St. Louis. It can be generally stated that the absence of crossbedding is an important negative feature in contrast to the Ste. Genevieve above and the Salem below.

Paleontology of the St. Louis. Although the St. Louis limestone is abundantly fossiliferous at several horizons, it is difficult to obtain identifiable specimens from the hard, dense beds, and its fauna is little known. Many fossils may be obtained from the chert associated with the limestone.

Probably the most important guide fossil to the St. Louis is the massive colonial coral *Lithostrotion canadense* (Fig. 4). It is readily

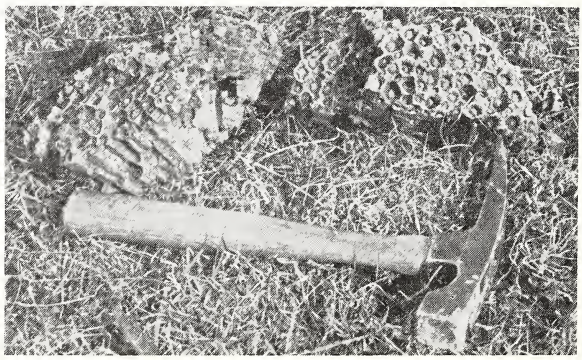

Fig. 4. Silicified *Lithostrotion canadense* from the St. Louis residuum near Corydon.

silicified and is a common constituent of the St. Louis residuum. In Harrison County this index fossil is not only limited to the St. Louis formation but it is also restricted to a single horizon within the St. Louis. This horizon is usually located 22 feet below the St. Louis-Ste. Genevieve contact and is so consistent over most of the area that it can be used for mapping purposes (Fig. 5). An exception was seen in the extreme southern portion of the area where the interval thickens to 37 feet. The silicified *Lithostrotion canadense* protrudes beyond the surface of the weathered limestone outcrop and is easily distinguished. On the fresh rock surface it can be recognized by the lighter color and the structure of the corallites.

Another species, *Lithostrotion proliferum*, is common in the St. Louis, especially in the upper part. It was not seen above nor below the St. Louis. This coral is readily silicified and can be collected in abundance from the residual material.

Bryozoa is also common in the St. Louis. Several genera, including *Fenestella*, may often be abundant, sometimes forming most of a single layer. Brachiopods constitute a large portion of the St. Louis fauna. Among the brachiopods the following genera have been recognized: *Productus*, *Spirifer*, *Echinoconchus*, and *Schuchertella*. Other fossils include *Melonechinus multiporus*, *Syringopora*, crinoids, and other specimens as yet unidentified.

General Lithologic Characteristics of the Ste. Genevieve Limestone. *Nature of Sediments.*—That the Ste. Genevieve is similar to the St. Louis in many respects is obvious in view of the difficulty in recognizing and differentiating these formations in the past. This description of the Ste. Genevieve will show some of these similar as well as contrasting characteristics.

The Ste. Genevieve in Harrison County is a jointed, thick- and thin-bedded limestone. Like the underlying St. Louis limestone there are two sets of joints, usually vertical, and are aligned approximately north and south, and east and west. Unlike the St. Louis, however, some of the joint planes are not vertical but cut the bedding planes obliquely, often in a very striking manner. This feature can hardly be called a distinct characteristic although it has been observed at numerous localities.

The Ste. Genevieve limestone ranges in texture from lithographic to material containing calcite grains the size of small shot. Strata of various degrees of crystallinity are common. In fact it might be said that as a whole the Ste. Genevieve is considerably more crystalline than the subjacent St. Louis. Throughout much of its extent the Ste. Genevieve is more or less oolitic, and this characteristic is an important one in differentiating it from the St. Louis. Some of the oolitic beds are hard and dense and the oolitic character can be seen only on close inspection. Contrasted with this, other beds of the oolite are coarse textured, resist fracture, and the spheroidal bodies are conspicuous, standing out prominently on weathered surfaces and being plainly apparent on freshly broken surfaces. The oolitic layers may also contain small fossils or fossil fragments. These layers are usually crystalline in character.

The Ste. Genevieve limestone is, as a whole, a strikingly pure limestone. Argillaceous material is present but not common. Shale beds are rare and the clayey material is usually in the form of argillaceous limestone. Dolomite is also present, particularly in the lower portions of the formation. Here the dolomitic strata commonly contain dolomite druses.

Flint and chert probably constitute the greatest impurity in the Ste. Genevieve. Although it is not notably a cherty formation, numerous layers and nodular masses of flint and chert do occur, particularly in the lower part. The most notable occurrence of chert in the Ste. Genevieve is the Lost River chert of Elrod (1899). This is not chert in the true sense of the word but rather is highly fossiliferous, siliceous limestone which, on being exposed to the weathering agencies, is leached of its calcium carbonate. In some cases the lime is completely replaced by siliceous material. This chert ranges in thickness from several inches to 3 feet. Occasionally not one but two such chert horizons occur, separated

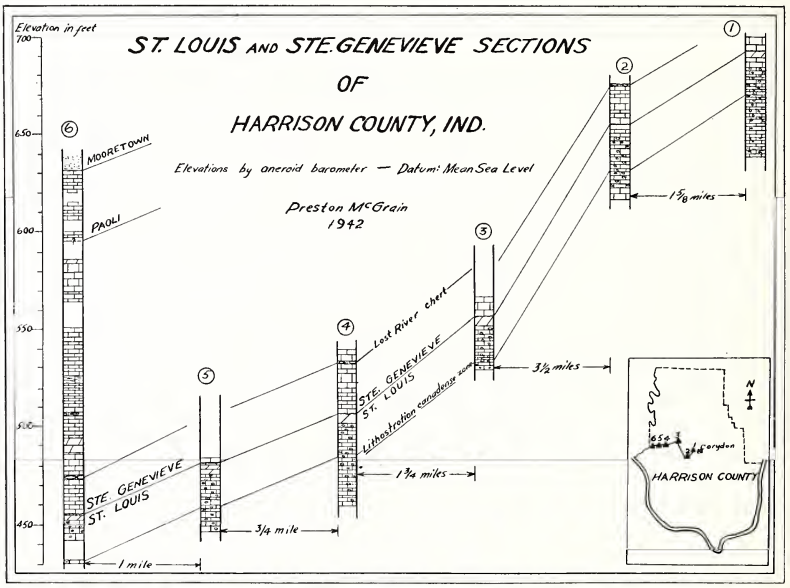

Fig. 5.

by about 2 feet of limestone. This chert is usually easy to recognize and is consistently found 15 to 22 feet above the base of the Ste. Genevieve (Fig. 5). At another horizon the oolitic limestone is silicified and the resulting chert preserves the oolites which are also silicified. In the middle Ste. Genevieve strata of the western portion of Harrison County there is a concentration of beds of black flint of high quality. Nodules and irregular masses of flint are also present in the Ste. Genevieve, and are most common in the lower beds.

No sandstone was observed in the Ste. Genevieve in Harrison County, but locally sand grains occur in the mass of limestone.

Color of the Rocks.—Because of the general lack of impurities the Ste. Genevieve is a light colored stone. The color of the limestones on the fresh surface ranges from pure white to medium gray, the greater portion of the formation being a light gray color. The presence of argillaceous or magnesian material colors the stone blue-gray, green-gray, brown-gray or buff. Frequently the surface is stained reddish brown due to the oxidation of the ferrous iron which the formation contains. The presence of iron is also evidenced by the red color of the residual material. The Ste. Genevieve is quite noticeably lighter colored limestone than the St. Louis. Although this characteristic does not hold true for each individual bed it does apply to the formation as a whole.

Bedding.—The Ste. Genevieve limestone is both a thick- and thin-bedded formation. The strata range from a few inches to more than 6 feet. It is generally massive appearing, more so than the St. Louis. The strata are usually marked by sharp bedding planes. And, like the St. Louis bedding planes, they are often in the form of stylolites.

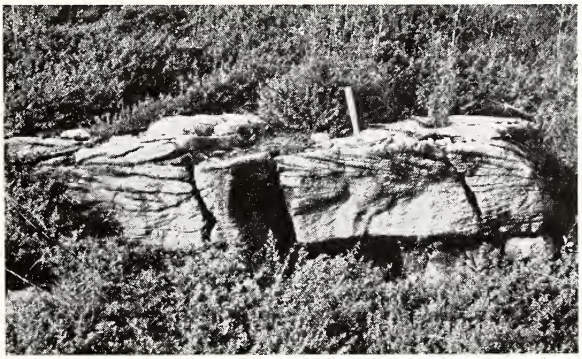

Fig. 6. Cross-bedding in the upper Ste. Genevieve limestone along highway 62, 2¼ miles northwest of Corydon, Sec. 27, T. 3 S., R. 3 E.

Cross-bedding is a conspicuous feature of the Ste. Genevieve formation (Fig. 6). Although the presence of cross-bedding is not an infallible criterion for distinguishing this formation from the subjacent St. Louis it is an important characteristic. The cross-bedded strata are usually oolitic stone. Quite often this structural feature is made visible on surfaces etched by weathering.

Weathering of the Rocks.—Chemical agents are the dominant factors in the weathering of the Ste. Genevieve rocks. As in the St. Louis, solution in the Ste. Genevieve takes place mainly along the joints and bedding planes, thus weathering it to a cavernous condition. Wyandotte Cave, which is located in Crawford County less than two miles from the Harrison-Crawford county boundary line, is developed almost entirely in this limestone. The thin-bedded, hard, fine-grained beds of the Ste. Genevieve limestone weather much like most of the St. Louis, but the

exposed massive, oolitic and granular-crystalline strata are characteristically pitted, honeycombed and rounded.

Paleontology of the Ste. Genevieve. Fossils are also difficult to obtain from this massive limestone formation and consequently its fauna has never been thoroughly collected.

Platycrinus penicillus has long been recognized in the Eastern Interior Basin as a guide fossil to the Ste. Genevieve. In Harrison County the small, elliptical, spiny plates of this crinoid were never seen by the writer in the overlying Chester formations or in the underlying St. Louis. Because of its restricted occurrence it was used frequently to identify the Ste. Genevieve in the field. The Lost River chert, previously mentioned under Lithologic Characteristics of the Ste. Genevieve, is highly fossiliferous. It can, perhaps, be best described as containing a brachiopod and fenestellid fauna. The fauna of the rest of the Ste. Genevieve includes *Syringopora*, *Pentremites*, productids, and crinoids.

Stratigraphic Boundaries. In order to ascertain the thicknesses of the St. Louis and Ste. Genevieve limestones it was first necessary to establish the limits of these formations. Since little detailed work has been done on the internal stratigraphy or upon their boundaries in Indiana, much detailed study in the field on these formations was imperative.

Salem-St. Louis Contact.—Although the Salem-St. Louis contact is not always sharp the limestones themselves can be recognized on the basis of both lithologic and faunal differences. The hard, generally massive, crystalline, sometimes cross-bedded Salem limestone is quite different from the thin-bedded, cherty, argillaceous, non-crystalline lower St. Louis. They are often easily distinguished by the manner in which they weather. The weathered surface of the Salem is characteristically pitted and honeycombed while the thin-bedded, argillaceous lower St. Louis assumes a shaly appearance when exposed to the weathering agencies. In Harrison County the lower portion of the Salem is noticably shaly and fossiliferous. This horizon correlates with the Somerset member of the Salem of Stockdale (1939). Another shaly zone was observed at the top of the Salem in a road cut one-half mile west of the village of Crandall. Faunally, the Salem is best characterized by a foraminifer *Endothyra baileyi*.

St. Louis-Ste. Genevieve Contact.—The contact of the St. Louis and Ste. Genevieve limestones has received little study. In fact the difficulty in picking out a contact has caused much delay in the proper delimitation of these formations in Indiana (Fig. 7). The division, when indicated, was placed by many geologists at the upper limit of the Lost River chert horizon. This idea seemed to hold in Indiana literature until 1931 when Malott, speaking of solution features in the Lost River region, placed the base of the Ste. Genevieve limestone some 15 or 20 feet below the Lost River chert. The same year, Bates, quoting Malott, states that the division between the St. Louis and the Ste. Genevieve limestones in Indiana is not at the Lost River chert horizon but at an unconformity 10

to 20 feet below the Lost River chert. He adds that Malott's evidence in support of this conclusion are oolitic beds and the fossil crinoid *Platycrinus penicillus*, a form thought to be restricted to the Ste. Genevieve, below the Lost River chert; and also the absence of *Lithostrotion canadense* and *L. proliferum* in or immediately below the chert zone.

Fig. 7. Contact of the St. Louis and Ste. Genevieve limestones in a road cut along highway 62, 5 miles west of Corydon, Sec. 20, T. 3 S., R. 3 E., marked by head of hammer.

Since oolites seem to be a very important characteristic of the Ste. Genevieve it is common practice to place the St. Louis-Ste. Genevieve contact more or less arbitrarily below the lowest prominent oolitic beds. Butts (1918) and J. M. Weller (1931) recognized the prominence and importance of the oolites as a distinctive lithologic feature in nearby Kentucky. As arbitrary as it might seem to be, this basis for division is not only very convenient but also is in harmony with the other criteria. With one exception the lowest oolitic bed ranged from nothing to 1½ to 2 feet above the top of the St. Louis. An oolitic bed, thought to be in place, was observed along a road at the top of the Ohio River bluff in Sec. 6, T. 6 S., R. 4 E., and was estimated to be 50 to 60 feet below the top of the St. Louis. Further observations failed to reveal the St. Louis beds of similar lithology in Harrison County. Neither was this bed found at a correlative position at any other point along the Ohio River.

The elliptical, spiny crinoid plate of *Platycrinus penicillus*, mentioned previously, was also used successfully by Butts (1918) and J. M. Weller (1931) in Kentucky for a distinguishing faunal marker. In Harrison County, Indiana, the writer found this diagnostic fossil in the lowest of the Ste. Genevieve beds but never in the St. Louis strata.

Besides these characteristics, much of the Ste. Genevieve differs from the St. Louis in being much lighter in color. This change is noticable at the contact. The St. Louis is dull gray, medium to fine-grained limestone contrasted with the white or whitish gray, crytalline Ste. Genevieve. In a number of places where the contact is well exposed over some considerable distance the contact is noticably undulating or wavy.

Another distinction, although not as striking nor as useful, is the difference in the manner in which these two formations weather. Because of its physical as well as chemical properties the Ste. Genevieve often weathers to a rounded surface. Honeycombed surfaces due to differential solution are common. This feature, however, is not nearly so well developed in the Ste. Genevieve as it is in the Salem limestone.

The *Lithostrotion canadense* zone, restricted to the St. Louis, and the Lost River chert horizon near the base of the Ste. Genevieve provide excellent clues for the location of the contact.

Ste. Genevieve-Paoli Contact.—The unconformity which separates the Ste. Genevieve and the Paoli is the most conspicuous stratigraphic break noted in this study. It is expressed in Harrison County as a reworked and recemented limestone conglomerate or breccia 1 to 3 feet thick. This brecciated zone was observed on Pilot Knob, NW quarter Sec. 36, T. 3 S., R. 3 E.; at the west end of a railroad tunnel in Sec. 21, T. 2 S., R. 3 E.; in a quarry in the W half Sec. 10, T. 4 S., R. 2 E.; and along the bluff overlooking the Ohio River in Sec. 11, T. 5 S., R. 2 E.

A thin calcareous sandstone is sometimes found at the base of the Paoli immediately overlying the brecciated zone. This horizon in Harrison County varies from nothing to 2 inches in thickness and possibly represents the Aux Vases sandstone of the Illinois section.

Lithologically the Paoli and the Ste. Genevieve limestones are similar in many respects and the boundary must be distinguished faunally and by the presence of the brecciated zone. The Paoli usually contains two calcareous shale breaks, either of which may contain many Chester fossils. In a road cut or quarry face these horizons are easily recognized and immediately suggest the Paoli formation.

Paoli-Mooretown Contact.—Because the brecciated zone described above is recognized with great difficulty on weathered outcrops and because talus and residual material often hide this marker it is often necessary to locate the top of the Paoli in order to approximate the position of the Ste. Genevieve-Paoli contact. The Mooretown is a sandstone and its position may frequently be ascertained by its influence upon the topography. It ranges in thickness from 20 to 60 feet in Harrison County. It is a coarse grained, iron stained sandstone, and is sometimes strongly cross-bedded. Markings of the plant fossil *Stigmaria* are frequently present and serve to characterize this sandstone formation. Its base is 30 to 35 feet above the Ste. Genevieve-Paoli contact.

Thickness of the Formations. The best exposures of the St. Louis are found along Indian Creek, Buck Creek, and the Ohio River. The Ste. Genevieve is also well exposed along portions of Indian Creek and the Ohio River as well as Blue River. The very nature of the rocks has limited the number of exposures satisfactory for ascertaining thicknesses. Because of the deep mantle of residual material which covers most of the area, well records, when present, are of little aid. The relatively low relief, the position with respect to overlying resistant beds, and the great thickness made the St. Louis the more difficult of the two to compute.

As far as the writer knows, there has never been any measurement of the St. Louis or Ste. Genevieve in Harrison County. Ashley (1903) gives the following description of the thickness of the Mitchell:

> Perhaps the best estimate of the thickness of the Mitchell (in southern Indiana) was made at Corydon. The top of the Mitchell is found in Pilot Knob at 265 feet above the creek, according to barometer. The bottom of the Mitchell is last seen at the quarry four miles east of Pilot Knob. The average dip of the strata along the Airline railway, a few miles north, is found to be approximately 33 feet to the mile. If the same dip holds between the foot of Pilot Knob and the quarry the bottom of the Mitchell should be 100-125 feet below the stream at the foot of the Knob, allowing for the descent of the stream, or between 350-400 feet below the top of the Mitchell in the Knob.

The writer measured the Paoli at Pilot Knob and found it to be 30 feet thick. The interval between the Lost River chert and the base of the Paoli is 104 feet. Assuming the Lost River chert to be 15 to 20 feet above the St. Louis the thickness of the Ste. Genevieve is 120 to 125 feet thick at this point. It follows, if Newsom's figures are correct, that the St. Louis is 205 to 245 feet thick.

The thickest St. Louis section observed by the writer was along the Ohio River in the W half of Sec. 6, T. 6 S., R. 4 E. Here 229 feet of St. Louis strata were observed from the valley level to the top of the River bluff. Alluvium in the valley and a thick blanket of residuum capping the upland prevented the ascertainment of the full thickness of this formation. Since this section reached neither the *Lithostrotion canadense* zone in the upper St. Louis nor the Salem formation it is the opinion of the writer that the total thickness of the St. Louis is 265 to 280 feet in the extreme southern portion of Harrison County.

The thickest section of Ste. Genevieve, 173 feet, was observed down the river from the above section in Sec. 14, T. 5 S., R. 2 E. Although the underlying St. Louis strata were not exposed it is thought that the lowest exposed beds represent the base of the Ste. Genevieve formation. Another complete Ste. Genevieve section may be seen near the Harrison-Crawford county boundary in Sec. 26, T. 3 S., R. 2 E. (Fig. 5, Stratigraphic section 6). The Ste. Genevieve formation at this locality is 141 feet thick.

Conclusions

It has been the aim of this paper to afford a more precise picture of the St. Louis and Ste. Genevieve formations in Harrison County, Indiana; to bring to light certain fundamental characteristics of these formations which may apply to other areas; and to link the Middle Mississippian stratigraphy of extreme southern Indiana with previously studied areas.

This paper has attempted to show that the St. Louis and Ste. Genevieve are distinct and separate formations and, as such, may be mapped in the field. Zones and definite horizons within these formations were also recognized as mappable units. Most conspicuous of these were the *Lithostrotion canadense* zone in the upper St. Louis, and the Lost River chert in the lower Ste. Genevieve. The writer has used both horizons for mapping structure and has found them highly satisfactory. Other units were recognized locally but time did not permit the determination of the extent of these horizons. Of the two formations the Ste.

Genevieve undoubtedly has the most horizons which can be traced from one locality to another.

Because of reasons previously given the thicknesses of the St. Louis and Ste. Genevieve formations were difficult to obtain. From the data gathered in the field it was found that the formations thicken southward and westward. However, in view of our knowledge of these formations in counties north and west of Harrison County this is not a surprising fact. As far as the writer is aware, the exposed St. Louis and Ste. Genevieve in Indiana attain their maximum thicknesses in southern Harrison County.

The unconformity between the Ste. Genevieve and the Paoli represents the most conspicuous stratigraphic break observed in this study. Another unconformity, although not as conspicuous, is the boundary between the St. Louis and the Ste. Genevieve.

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Use of Electrical Logs in Subsurface Studies in Indiana

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Electrical logging of wells has been used to obtain subsurface data by the Oil Industry for several years. In each log two types of electrical diagrams are obtained, the self potential, which gives a record of the self potential generated naturally in a drill hole and the resistivity

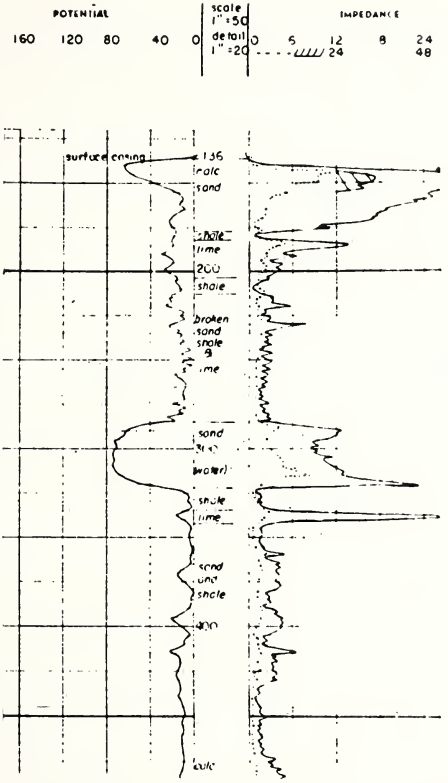

Fig. 1. Electrical log showing self potential and resistivity curves.

diagrams which are the result of the difference in potential registered by two electrodes from an electrical current conducted into the ground.

Self potential is the result of electro-filtration and electro-osmosis.[2] Electro-filtration is caused by the passage of the fluid from the hole into

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[2] Electrical Well Logging by the Houston Geological Society Study Group. Bull. Amer. Assn. Petrol. Geologists Vol. 23, No. 9, p. 1288.

a porous substratum or if the formation pressure is higher than the hydrostatic pressure of the fluid in the hole, the passage of the fluid into the hole. The latter condition rarely occurs. Electro-osmosis occurs when the drilling fluid comes in contact with the fluid in the formation. If the salinity of the water in the sand is higher than that of the drilling mud the current enters the formation. If the salinity of the drilling fluid is greater than that of the formation, the current enters the hole. The former case is the normal condition. Since these conditions can occur only where porous strata are penetrated the self potential diagram (Fig. 1) is indicative of the porosity of the formation.

The electrical resistivity of rocks varies considerably due to the physical character and water content (Fig. 1). The contained water may be connate, or fresh or salt water which is free to circulate. In addition to water, the pore spaces may contain oil or gas, which are non-conductors, and show high resistivity. Formations carrying salt water show low resistivity. High resistivity in permeable formations may be due to fresh water, sulphur water and oil and gas. Non-permeable formations, such as limestone, coal and well-cemented sandstone, show high resistivity.

Therefore, from the electrical log of a well we are able to determine the lithologic character of the formations penetrated, the character of the fluid content of the porous strata and we also have an index to the porosity of the formation. The electric log affords an accurate measurement of the depth to various key horizons used in contour maps of subsurface formations. Also, a number of distinctive coal horizons can be determined and correlated by use of electric logs. Although the coal beds are generally too thin to show up prominently on the electric logs, the beds immediately above and below the coal are indicated well enough to correlate the sequence of strata.

An electrical log cross-section in the New Harmony field, Illinois (Fig. 2), which connects with the Griffin field in Indiana, shows the characteristic lithology of the Chester formations in that area. Log No. 7, of the cross-section, is a sample study adjusted to the electric log of the well. Note the high resistivity and low potential of the limestone beds and the high potential and low resistivity as shown by the Tar Springs sandstone which carries salt water in that area. The Aux Vases sandstone shows fairly high self potential and low resistivity which would normally be interpreted as a water sand. Investigations have shown that, due to the large amount of calcium carbonate, cement and connate water, the resistivity curve indicates salt water, whereas actually the formation contains much oil.

Many local problems which develop in the use of electric logs are overcome when they are checked with an occasional sample study in the area. A sandstone near the surface which carries fresh water will probably appear to be limestone as there is little or no self potential developed and the fresh water will give a high resistivity reading. A well-cemented, hard, tight sandstone may appear to be limestone. Also, it is often difficult to determine the presence of oil or gas in limestone and particularly in dolomite.

Electrical logging has been employed recently in water well drilling where further information regarding the thickness and porosity of the aquifer is desired. The Illinois Geological Survey has conducted experiments in electrical logging of water wells and their results have been highly favorable, particularly so in old wells where no records have been kept.[3] The Missouri Geological Survey plans to use electrical logging in

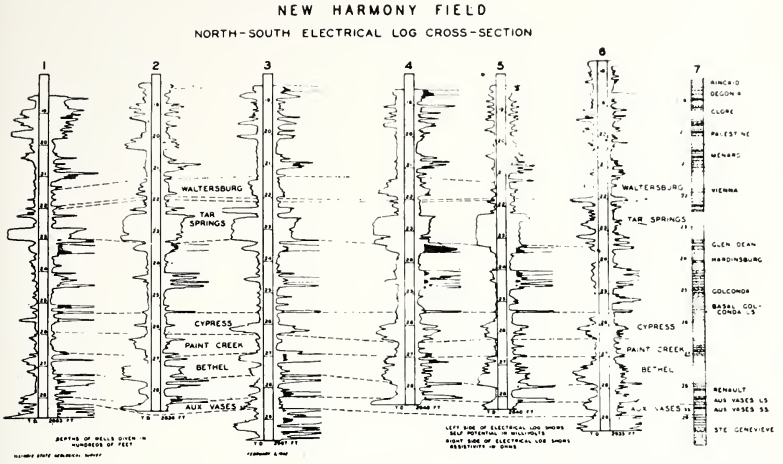


Fig. 2. North-South electrical log cross-section in the New Harmony field.

water wells, particularly in the Cretaceous and Tertiary sands of southeastern Missouri and in the dolomite section in the water wells in the Ozark Region.[4] In the Dolomite wells they want to determine the zones of porosity which might be acidized to increase the flow of water.

Electrical logs have been run on approximately 500 oil and gas test wells in Indiana, practically all of which are in the southwestern part of the State. The Indiana Geological Survey has received copies of many of the logs and it is contacting the operators in an effort to get all of the logs that have been run, as they will be of great assistance to the Survey in subsurface studies in the State.

[3] Carl A. Bays—personal communication.
[4] H. S. McQueen—personal communication.

Electrical Earth Resistivity Surveys

WALLACE W. HAGAN,[1] Indianapolis

One of the natural and quite variable properties of earth material is to offer resistance to the passage of an electric current conducted into it. It is advantageous to be able to measure the resistance of predetermined volumes of earth material to given depths, and such measurements are possible by the use of certain methods and electrical apparatus. An electrical earth resistivity survey consists of a survey of an area to determine the average apparent resistivities to various depths at different stations. The interpretation of the data obtained in such a survey may be used in a practical manner to determine:

1. The depth to bedrock for highway and dam construction.
2. The depth of a body of water and nature of the underlying material.
3. The locations of ore bodies and placer deposits.
4. To aid in the location of possible water-bearing sand and gravel deposits.

In 1916, Frank Wenner[2] introduced a method of measuring effective resistivity of a given volume of earth material to a given depth. Later, in 1925 and 1927, Gish and Rooney, of the Department of Terrestrial Magnetism, Carnegie Institute of Washington, designed and developed an instrument for electrical earth resistivity surveys. With this apparatus and the Wenner method they collected much vital resistivity data. Other researchers have carried on much theoretical work.

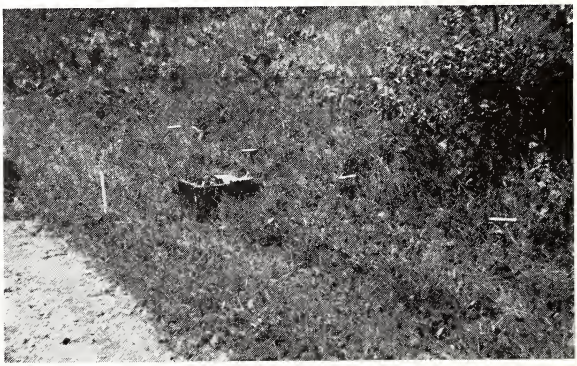


Fig. 1. Instrument set up in field.

The method (Fig. 1) consists of placing four electrodes in a straight line in the ground at equal distances apart on a relatively plane surface.

[1] Geologist in charge of Ground Water Exploration—Division of Geology, Department of Conservation.

[2] Bulletin of the Bureau of Standards **12**:469-478.

Then a commutated current is conducted into and through the ground between the two outer electrodes, and the voltage drop is measured between the two inner electrodes. The depth to which each reading is taken is determined empirically by the separation of any two electrodes. The formula applied for the determination of the average apparent resistivity of the entire thickness of material being measured between the inner electrodes is:

$$\rho = 2 \pi a V/I$$

where ρ equals the average apparent resistivity, a the distance between adjacent electrodes, V the voltage drop or potential between the inner two electrodes, and I the true current through the ground.

The voltage drop is measured between the inner electrodes because the paths of the current through this section are more evenly distributed and more nearly parallel than at the electrodes where the current is introduced into the ground. There it is radiating from the electrodes, the paths are closer together, and interference is greater due to high contact potentials.

The readings taken on the instrument are in direct current. The current conducted into the ground is alternated in order to reduce interference from polarization at the electrodes and stray earth currents. And the potential difference between the inner electrodes is rectified so that readings can be taken with the direct current potentiometer, and any outside potentials in the earth are reversed so rapidly they do not register.

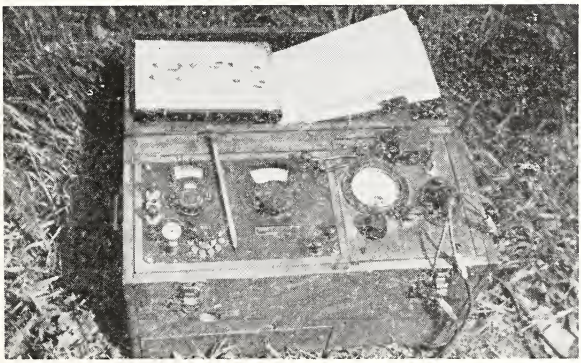


Fig. 2. Close-up view of instrument panel.

The instrument (Fig. 2) possesses a Leeds and Northrup potentiometer, on the left side of the control panel, the purpose of which is to measure the voltage drop. Two forty-five volt B batteries connected in series furnish the direct current the output of which is controlled by a rheostat and registered on an ammeter on the right side of the control panel. A double commutator is inserted into the circuit between the meters and the leads to the electrodes, and it is turned by a hand crank.

The Illinois State Geological Survey in recent years has used this method successfully in the location of ground water supplies in sand and gravel deposits in over 90 per cent of the surveys made for that purpose.

The Indiana Division of Geology, of the Department of Conservation, has inaugurated a program of using electrical earth resistivity surveys to assist in the location of ground water supplies in Indiana in sand or gravel deposits in glacial drift or alluvium above the bedrock. Such surveys are based on the principle that sand, gravel, limestone and sandstone have higher resistivities than clay, silt, till or shale, in or upon which, the sand and gravel might lay. All the data are plotted on graphs, and maps are prepared. Knowing the general range of resistivities for each type of material and taking into consideration the interpretation of the resistivity data in the light of all known geological information for the area under consideration, the favorable water-bearing deposits in the area are outlined and the locations for test drilling are recommended.

The Indiana Geological Survey is making this service available to the public, especially to municipalities, industries engaged in the War Effort and to various schools in the War Department. The survey furnishes the instrument, equipment, technician and report free of charge. The ones for whom the survey is to be made furnish the labor to run the electrodes and purchase the stakes for station locations.

Drouths In Indiana

Stephen S. Visher, Indiana University

Although Indiana is relatively fortunate as compared with most of the world in its rainfall dependability, and seldom has prolonged severe drouths, nevertheless local deficiencies of rainfall occur for at least short periods nearly every year. As part of a comprehensive study of the climate of the State, studies have been made of the frequency and intensity of drouths, and of their regional contrasts within the state. Part of this investigation was aided by a research grant from the Academy made in 1940.

Drouths in Indiana are of three chief types: those due to a) little precipitation, b) exceptionally great water requirement at a time when only a moderate amount is available, and c) a poor distribution of precipitation. The first of these types usually occurs whenever less than about half of the normal amount of precipitation falls during any months or season. The second type occurs, despite what in cool weather would have been a moderate amount of rainfall, whenever excessive evaporation is induced by exceptionally high temperatures for some weeks, or when there are hot drying winds. The third type of drouth occurs when, despite a normal monthly or seasonal total of rain, it falls torrentially at long intervals with much of it running away from sloping land. For example, a summer rainfall of two inches a month is not adequate to prevent a drouth on hillsides in Indiana if the four inches received in two successive summer months occur as "cloud bursts" at the beginning of the first month and the end of the second, with no rain at all for nearly two months between these rains.

Drouths occur in all parts of Indiana but there is considerable regional contrast in frequency and severity. Evidence of this is given in some detail beyond, but here a summary is desirable. Southern Indiana has more summer drouths than central Indiana. This is partly because it occasionally has more prolonged dry spells, and partly because there is more runoff from torrential rains, as a result of greater physiographic relief and a less absorbant average soil. The normal soil of southern Indiana is a poorer absorbant of hard rainfall than is that of central Indiana for two chief reasons. One is that much of southern Indiana was never glaciated and the rest was glaciated relatively long ago, since which time the soil has been much modified and no longer is a typical glacial soil. The other reason is that because of the much greater and more often torrential winter rainfall in southern than in northern Indiana, more of the top soil has been removed from sloping land by erosion. The top soil usually is a much more absorbing layer than is the subsoil.

Dry spells occur rather frequently in winter in northwestern Indiana, but aside from facilitating wind erosion of sandy soil and reducing domestic water supplies by lowering the water levels in

wells and streams, they do relatively little damage to agriculture. Indirectly they have in one respect aided agriculture by helping make much of that section a prairie region rather than a forested one. The drouths would, however, interfere with extensive industrial development except where water is readily available, as from Lake Michigan.

A third regional contrast in drouth in Indiana is an appreciably greater frequency of drouth in the western third of the state than in the eastern third. This is due partly because the average precipitation is less in the western third than in the eastern third; partly because drying winds from the drier west reach western Indiana relatively more often; third, because the western third of the state has a higher summer temperature, associated with its lower altitude and its position nearer the center of the continent, which warms up more in summer than does the eastern, higher, more humid region.

Exceptionally Dry Years

If a major drouth occurs whenever the annual precipitation is less than 85 per cent of normal, between 1880 and 1941 there have been seven drouths: 1894, 1895, 1901, 1914, 1930, 1934, and 1936. The deficiencies of precipitation for the average of the State were 9.7 inches in both 1930 and 1934, 8.9 inches in 1901, 8.4 inches in 1895, 7.9 inches in 1914, and 7.2 inches in 1894. The deficiency was only 5.6 inches in 1936, almost the worst year so far as crop damage is concerned, because of the very hot dry summer. The relatively large annual total of precipitation in 1936 was largely due to abundant rains near the beginning and end of the year.

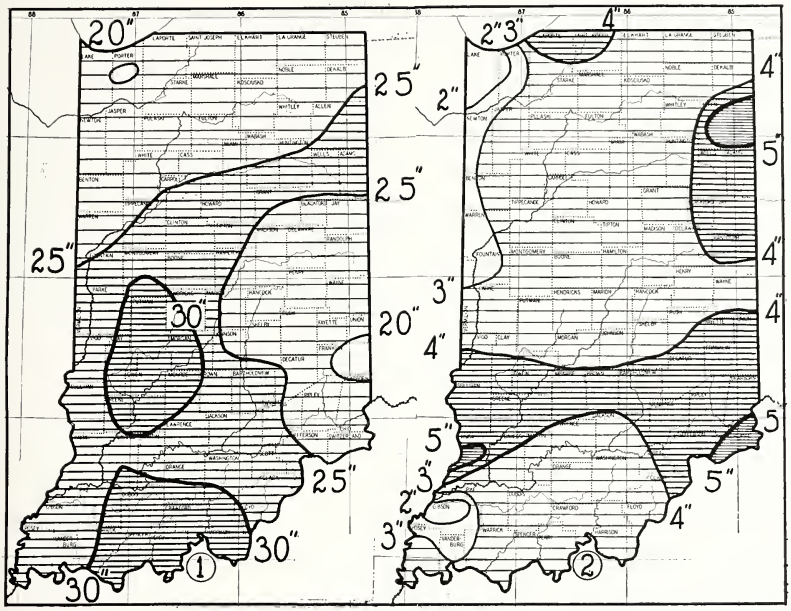
The two driest years (1930 and 1934) had state averages of 29.7 inches of precipitation, instead of the normal average of about 39 inches. They thus had about three-fourths the normal total. In almost half of the State, the driest year of record received less than 25 inches; two small areas have received less than 19 inches (Valparaiso, 18.1 in 1899; Brookville, 18.7 in 1934).

In the two worst drouth years, southern Indiana fared much worse than northern Indiana. In 1930 a zone bordering the Ohio River had a deficiency of rainfall (below the normal total received) totaling from 13 to 18 inches. Thus that zone received only about two-thirds of the normal total. In 1934, parts of south-central and southeastern Indiana had deficiencies of 20 to 23 inches; thus those areas received little more than half of the normal total. Figure 1 shows the precipitation in the driest year of record (not the same year everywhere).

Exceptionally Dry Seasons

A series of graphs have been prepared of the fluctuations in rainfall 1913-1939 for the northern, central, and southern thirds of the State, and for the state as a whole, and also for each of the four chief seasons and for the year as a whole. They reveal that the driest springs for the State as a whole were those of 1934, 1930, 1925, and 1914. In southern Indiana, 1914, 1925, 1930, and 1934 had exceptionally dry springs. Northern Indiana's driest springs were those of 1915, 1925,

1928, and 1934. Three consecutive springs, those of 1930, 1931, and 1932 were dry, and after a wet spring in 1933, 1934 was the driest for the 27 years studied. The driest summers of 1913-1939 in Indiana were those of 1936, 1930, 1933, 1922, 1913, in order of decreasing dryness. Dry autumns occurred in 1914, 1922-1924, 1938, and 1939 (the driest of that period). Northern Indiana had exceptionally dry autumns in 1914 and 1924, and southern Indiana, in 1929, 1935, and 1939. Of the winters, those of 1919, 1936 and 1938 were exceptionally dry (state average). The driest winters for northern Indiana were 1917, 1919, 1925, 1931, 1935, and 1936; for southern Indiana the driest winters were 1936 and 1925.



Figs. 1-2: Least Annual and Least Summer Precipitation ever officially recorded.

Regional contrasts in the frequency and severity of summer drouths are shown by various maps some of which are not here reproduced. Figure 2 shows that in the driest summer of record, a total of only from 3 to 4 inches was received in most of the State; three western stations received less than 2 inches. The largest totals (5.3, 5.5, and 5.6 inches) were received near the eastern margin of the State and at Vincennes.

Any summer month in Indiana which receives less than 1.5 inches of rainfall is distinctly dry. On this basis, the southern third of Indiana has more summer drouths than does Central Indiana, parts of it nearly twice as many. An area in south-central Indiana receives in one-ninth of the years, less than half of the normal summer rainfall. Figure 3 shows, however, that such dry summers are less than half as common in eastern as in western Indiana.

Dry Months

In April most of the State receives in the driest one-fifth of the years between 2 and 2.5 inches. The driest areas are in the north and the wettest in the south. In a dry May the total received is approximately 2.5 inches, least at the southwest, most in the northeast. In a relatively dry June the total for most of the State is close to 2 inches, with part of the southeast and extreme south receiving 2.5 inches. In a relatively dry July likewise, the total received is approximately 2 inches, with the driest areas situated in the southwestern quarter. Parts of Southern Indiana receive less than 1.5 inches during one-fifth of the Julys. For August, most of the State receives about 1.9 inches, with the least falling at the northwest and southwest. For September, the total is approximately 1.7 inches, with least in the southeast and the largest area of over 1.8 situated in the north. For October, also, the southeast receives least; central Indiana gets close to 1.4 inches.

The percentages of each of the months April-September which have received less than 1.5 inches of rainfall reveals an interesting increase month by month in the average percentage of such dry months. May (the wettest month in the year for the average of southern Indiana) has been a dry month a relatively large percentage of the time. June displays considerably less regional contrast than most of the months. During June, for most of Indiana, only one year in about fifteen receives less than an inch and a half of rain. Along the eastern border of the State only one year in twenty, on the average, is this dry in June, while on the western border approximately one June in ten receives 1.5 inches or less.

July is a more critical month than is June for Indiana farmers, because the yield of corn depends to no small degree upon July rainfall. July is also warmer than June, and hence water shortage is more serious. Moreover soil moisture, which normally accumulates in the winter and spring, is partly depleted by July. Indianapolis and most of the southwest quarter of the State receive in July less than 1.5 inches of rainfall during one-fifth of the Julys. A large part of the northern half of the State suffers from such drouths distinctly less frequently on the average than does the southern half.

The Driest Months of Record

Nearly all parts of the State have had during their driest June less than one inch of rain instead of the State average of nearly four inches. Stations which have had about one inch of rain in their driest June are Indianapolis, Vincennes, Vevay, Muncie, and South Bend. Cities which have had only half an inch in their driest Junes are Richmond, Bloomington, and Evansville; those which had less than one-fourth inch (the equivalent of only a moderate shower) during June include Fort Wayne, Madison, and Kokomo. Record dry Junes of less than one-tenth of an inch have been experienced at Terre Haute, Greencastle, and Princeton.

The driest Julys on record are decidedly dry. Almost all Indiana cities have had a July with as little as a half inch of rain. The chief

exceptions are in the northeastern corner, where about one inch fell in the driest July. Cities which during their driest July have received less than one-fourth inch of rainfall include Gary, Vincennes, Evansville, and Richmond.

August is somewhat less subject to extreme drouths than is July. Most of the Indiana Weather Bureau stations have recorded more than half an inch of rainfall in their driest August, and many of them have had about an inch. (For Indianapolis, the driest July and the driest August each received four-tenths of an inch.) The least rainfall recorded in any August was in three corners of the State: At Vevay, at the southeast, less than 0.1 inch; at Mt. Vernon, at the southwest, less than 0.14 inch; at Valparaiso, at the northwest, less than 0.25. Shelbyville and Connersville have also had an August with less than a quarter-inch.

The dates of the driest 3 of each of the 12 months have sufficient interest to justify their inclusion. The driest is given first, the least dry, third.

January 1925, 1931, 1919; February 1907, 1895, 1934; March 1910, 1915, 1937; April 1889, 1915, 1899; May 1934, 1925, 1932; June 1933, 1936, 1922; July 1901, 1894, 1936; August 1889, 1893, 1897; September 1897, 1908, 1939; October 1908, 1924, 1934; November 1904, 1917, 1914; December 1925, 1930, 1913.

Of these 36 exceptionally dry months during 1887-1939, 5 of them received a state average of less than half an inch of rain. Four of these were during 1904-1910 (Feb., Mar., Oct., Nov.) and the other in October 1924. Thus, although several months of 1930-1936 are included among the 36 driest months of these 53 years (636 months), and parts of the state had little rain, the state as a whole was less dry in any month than it was in the worst months of 1901-1910. (3 months of 1934 are among the 36 driest of record, 2 of 1936, but 1925 also had 3, and 1889, 1897, 1904, 1915 each had 2.)

Driest Groups of Months

May and June combined have been driest in southern Indiana, with a total rainfall of less than 2 inches. In the driest consecutive June and July, a total of less than an inch has been received in parts of northwestern and southeastern Indiana. In the driest July and August combined, three areas have received less than 1.5 inches, two in the south and one in the northwest.

In nine-tenths of the May-June and June-Julys, fully twice as much rain is received as in the very driest such pairs. In the drier one-tenth of the years, fully an inch more rainfall is received in eastern than western Indiana. July-August display less regional contrast, most of the State receiving between 3 and 3.5 inches.

In the driest one-tenth of the years a summer total of only 5.5-6.0 inches is received in most of Indiana; the corresponding data for the summer plus May is between 8 and 9 inches (fifty per cent greater). All four of these months are seldom dry in Indiana. For the driest summer and May combined, the totals for most of the State are between

6 and 7 inches; the largest area which received less than 6 inches was situated in the south. The driest pairs of months of 1888-1939 for the state as a whole were March-April, 1915, and August-September, 1897.

Percentages of the Warmer Months Receiving Less than Half the Normal Rainfall

Western Indiana is distinctly less fortunate than eastern Indiana with respect to this type of drouth. For May-June the longitudinal contrast or range averages about 50 per cent; for June-July it averages fully 75 per cent; and for July-August it is more than 100 per cent. Hence such dry July-Augusts are twice as frequent in western as in eastern Indiana. Thus while exceptionally severe drouths affect eastern Indiana somewhat less severely than they do the western counties, of the less severe drouths, eastern Indiana has a notably larger advantage, as it has far fewer lesser drouths than western Indiana. For the summer-plus-May, there is an average increase from the northeast to the southwest in the percentage of the years receiving less than half of the normal rainfall. Such drouths are more than twice as frequent for the average of the State's southewestern quarter as in the northeastern.

Length of Periods with Little or No Rainfall

Drouth-frequency-studies based on the year, season, or calendar month are inadequate because of the aribitrary limits of these periods. A harmful period of inadequate rainfall may be divided between two months, each of which had a normal total rainfall. Hence a study was made of the daily rainfall records of eight Indiana stations for the summer months of 22 years, 1914-1936. Three levels of rainfall deficiency were noted: the consecutive number of days 1) on which less than 0.1 inch fell, 2) on which as much as 0.25 did not fall in one day or 0.4 in two days, and 3) on which 0.5 inch of rain did not fall in one day or 0.6 in two days. The first of these limits means, during the summer, practically a rainless period so far as crops are concerned, although a rainfall of 0.1 inch may help grass somewhat. The second limit was chosen as a result of studies at the agricultural experiment station at Madison, Wisconsin, which indicate that as much as a quarter inch in one day or 0.4 inch in two days usually is necessary during a drouth to greatly help the corn crop. The limit of half an inch in a day or 0.6 in two days was selected because such a rain nearly always affords a real break in a dry spell. The stations chosen for study are rather well distributed over the State.

The following statements summarize the average number of times per summer that various sorts of dry periods occurred, based on the records for 22 summers at these eight stations.

About five or six times during an average summer a period of five consecutive days pass without as much as one-tenth inch of rain falling in any one day; about twice each average summer there are periods of ten consecutive days with that little rain; about once each average summer there are 15 such days. Twenty consecutive days with this small amount of rainfall occur only in about a third of the summers.

Thirty consecutive days of this type were not experienced at four of the eight stations; Indianapolis, however, had two such thirty day periods and Collegeville four. In the summer of greatest drouth of 1914-1936 (partly different summers at different stations) two such twenty-day dry periods occurred, four ten-day periods and seven to nine five-day periods. The greatest total number of consecutive days with no more than one-tenth inch of rain on any one day was 38 at Indianapolis, 35 at Collegeville; the least was 25 at Ft. Wayne. In the summer which had the fewest intervals without a tenth of an inch of rainfall, there were two or three four-day intervals and at three of the eight stations, one ten-day period.

Rainfall of a quarter inch in one day or 0.4 in two consecutive days are next considered. The average number of times in three summer months that five or more days passed with so little rain was between five and six. Ten-day periods of this type occurred an average of about three times a summer, fifteen-day periods occur in about two-thirds of the summers; twenty-day periods occur in about half the summers. In the 22 summers, there were an average total of nearly four

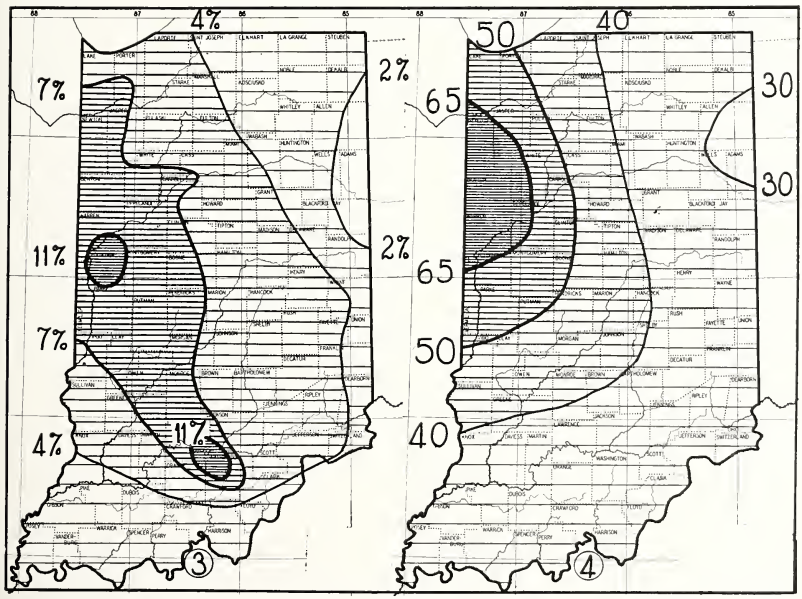


Fig. 3: Percent of Summers Having Less than Half the Normal Rainfall.

Fig. 4: Length of Summer Dry Spells. Greatest number of consecutive days without ¼ inch of rain (or 0.4 inch in 2 consecutive days).

spells of 30 consecutive days of this type. The maximum number of times per summer that five consecutive days of this type occurred was eight, the least number was three; the maximum number of ten consecutive days of this sort was five; the minimum was one or two; of

fifteen-day intervals, the maximum number was three, the minimum was zero; the maximum for twenty-day periods was two, the minimum was zero. The greatest number of consecutive summer days of 1914-1930 which did not have a quarter inch rain on any one day vary from thirty at Ft. Wayne to 65 at Lafayette and Collegeville. (Fig. 4)

Rainfalls of a half inch in a day or 0.6 in two days are not much less common in dry summers than are falls of a quarter inch. This is because dry spells usually are terminated by powerful thunderstorms most of which yield at least a half an inch of rain. In the average summer there are about three ten-day spells without a half inch rain; about two fifteen-day spells, and an average of more than one twenty-day spell. Thirty-day spells of this type occur in almost half of the years. The maximum number of consecutive days without a half inch rain varied in the 22 years from 42 to 92.

Another Study of Drouth Expectancies

A study by the U. S. Soil Conservation Service of drouth expectancies in the United States included three Indiana stations, Delphi, at the northwest, Greencastle, at the west-central, and Madison, at the southeast. From data of numerous stations scattered over the nation a series of seasonal maps were prepared. The Indiana parts of these maps may appropriately be described. This is especially appropriate as the detailed study summarized in the preceding paragraphs dealt only with the summer while the study now to be summarized includes each of the seasons.

These maps reveal that Indiana is comparatively free from prolonged drouths, if a drouth is defined as a period during which for more than ten consecutive days the total precipitation is less than one-tenth of an inch on any two consecutive days.

During each normal Indiana spring there is one period of about two weeks in duration without this much rain; in one spring out of five, such a drouth lasts about 2½ weeks, except in an area near the south end of Lake Michigan where it lasts about three weeks.

In the driest spring in an average decade, a spring drouth as here defined prevails for three to four weeks, except in the northeastern one-eighth of the State, which has a drouth for somewhat less than three weeks.

During each average summer in Indiana an almost rainless period of about two weeks' duration is to be expected in all parts of the State. Once in five years, a three-week drouth occurs, while once in a decade, a summer period of about four weeks occurs during which almost no rain falls.

Normally every autumn all of Indiana has a drouth lasting for about two weeks. Once in five years, the autumn drouth lasts for three to four weeks. Once in a decade it lasts for about thirty days except just east of the south end of Lake Michigan and also in the southeastern corner of the State where its duration is slightly less than thirty days.

During every normal winter all parts of Indiana have a drouth as here defined of about two weeks' duration. Once in five winters, three to four consecutive weeks without appreciable precipitation occur, except at the southwest where the rainless period is somewhat less than three weeks long. In the driest winter of a normal decade all of Indiana has about four consecutive weeks with little or no precipitation. In other words, during each quarter of each normal year, there is a period of about two weeks in length with very little rainfall, once in five years the drouth period extends to about three weeks, and during the driest year of a decade, drouth prevails for about a month, or a third of the length of each quarter-year, except in spring when the maximum duration is somewhat less than four weeks. Once in twenty years, the study summarized in the previous section of this paper shows, there are periods of little rainfall which are appreciably more protracted than are the longest such periods of a normal decade.

Growing-Season Precipitation Effectiveness Contrasts

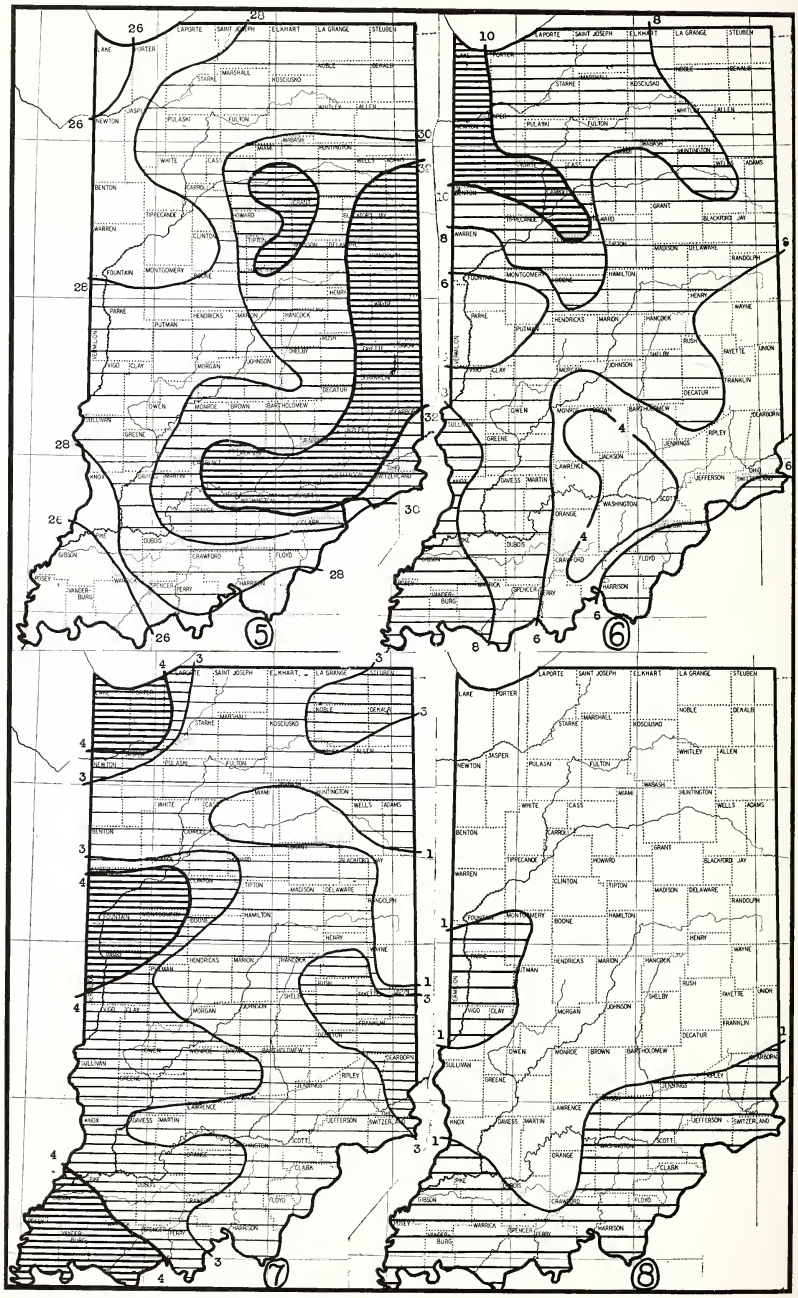
The Atlas of Climatic Types of the United States 1900-1939 was issued in 1942 by the Soil Conservation Service of the U. S. Department of Agriculture. A series of 40 maps for the growing season (March through August) shows the areas which, in each of the 40 years, were arid, semiarid, subhumid, and humid. Results of a detailed study of the Indiana parts of those maps by the present writer may advantageously be summarized.

The accompanying 4 maps were made by combining the relevant data of each of the 40 maps. Map 5 shows that for the eastern part of the State, about four-fifths of the crop-growing seasons are moist enough to be classed as humid. Along the western border of the State, however, only about two-thirds of the crop seasons are humid. In the southwestern and northwestern corners of the State, only about 26 of the 40 years studied were humid.

Map 6 shows the number of crop seasons which were moist subhumid, the type next drier than humid. This map shows that this type is most frequent at the northwest, where about a fifth of the crop seasons are moist subhumid; such seasons are less common at the southeast, occurring in less than a sixth of the years.

Map 7 shows that in the western part of the State, about a tenth of the crop seasons are dry enough to be classed as dry subhumid. Midway between the eastern and western margins of the State, only about two seasons in 40 were this dry. Most of the southern half of the State had about 3 such seasons while much of the northern half of the State had only one or two which were that dry.

Although the crop seasons of 1934, 1936, 1941 and various other years were locally dry enough during parts of the season to seriously damage the corn crop, the crop-season as a whole was driest in 1930. Then a wide belt along the Ohio River and also a section including Vermillion, Parke, and parts of the adjacent counties (see Map 8) were dry enough to be classed as semiarid, a rainfall condition characteristic of the short-grass plains of western Kansas and Montana.



Figs. 5-8: Climatic Type Prevailing During The Crop-Growing Season (March-August). Times per 40 years (1900-1939) that each type prevailed: Fig. 5, Humid; 6, Moist Subhumid; 7, Dry Subhumid; 8, Semiarid.

The most favored part of the state so far as rareness of relatively dry crop-seasons, according to the data analyzed on these maps, is the northeastern central part of the State. The least favored areas are the southwest and northwest corners, and an area along the western margin about midway between these corners. The counties bordering the Ohio River are apparently most likely to be exceptionally dry in summer.

The prospects, therefore, that any crop-growing season will be normally moist are about three to one in most of the State; they are four to one near the eastern margin. The chance that it will be moderately dry (dry subhumid) are only about one in ten; that it will be decidedly dry (semiarid) are less than 1 in 40 in most of the State, except the southern counties and part of the western margin of the State. The chance that the crop-growing season will be somewhat drier than normal (moist subhumid instead of humid, which is the normal condition) is about one in five in the southwestern and in most of the northwestern quarter; in part of the latter area, however, the chances of a moist subhumid condition rather than a humid one are about one in four. The chances of such moisture conditions are about one in seven in much of eastern Indiana, where several counties in the belt extending from Wayne (Richmond) to Crawford counties have only about one chance in eight or ten of having a moist subhumid growing season. In other words, a moist subhumid growing season occurs only about half as frequently in the southeastern part of the State as in the northwestern.*

* In addition to a grant from the Academy, this study was aided by help supplied by the National Youth Administration and by a grant from the Graduate School Research Fund of Indiana University.

PSYCHOLOGY

Chairman: F. D. Brooks, DePauw University

Mr. W. A. Kerr, Personnel Research Department, RCA Manufacturing Company, Indianapolis, was elected chairman of the section for 1943.

A study in changes in scores on the American Council psychological examination during a three-year period. E. L. Welborn, Indiana State Teachers College.—The American Council Psychological Examination was repeated in three groups of approximately ninety college students after intervals of one, two, and three years, respectively. A comparison of the original scores and the scores on the repetition was made. The results seem to indicate that mental growth as measured by intelligence tests continues during college years.

Psychological effects of music as reported by one hundred sixty-two defense workers. W. A. Kerr, RCA Manufacturing Company, Indianapolis.—A printed form, "Feelings About Music," containing six feeling scales designed to measure effects of music on feelings toward associates, tiredness, nerves, digestion, monotonous work, and worries was administered to 162 men preparing to enter defense industries. Means and standard deviations for each of the six scales were given along with a matrix of intercorrelations and the results of a profile analysis. Correlations between total "feeling" score and certain other variables were also reported. Results of the study tend to confirm favorable results reported from the use of music in industry.

The Postural Factors in Shock-Shock Conditioning

N. H. Pronko, Indiana University

Introduction. Recent investigation in the field of conditioning has tended in the direction of a more precise control and a more subtle analysis of the conditioned response situation representing many attacks on special problems from various lines of approach. Perhaps foremost among the methods employed have been those utilizing specially designed apparatus for the study of motor responses (1, 3, 6), action potential techniques, and surgery (9). Another line of study has employed drugs of both excitatory and depressant nature (5, 8, 11, 14), and has yielded rather contradictory results. The latter method would seem to recommend itself as being superior to extirpation since one can inactivate, excite, or depress behavior of animals to a desired degree through well-standardized doses and still maintain the animal in an intact condition for future retention and other tests.

Utilizing such a method, Headlee and Kellogg (8) at the Indiana University Laboratory in 1940 investigated the rate of conditioning of dogs injected with the depressant drug, Nembutal. Using a refined flexion conditioning technique, they found that conditioning proceeded at a greatly retarded rate under drug as compared with non-drug training. These investigators were able to keep the unconditioned stimulus (shock) constant in accordance with a behavioral criterion, namely a four-inch flexion. But they are rightfully skeptical about the "constancy" of the conditioned stimulus which was *fixed* at 50 db. above the human threshold. The present investigation was in part carried out as a check on their findings.

More pertinent to the present study, however, are the results of certain experiments on postural variables in conditioning. For example, Yoshioka (16), in studying handedness in rats, concluded that laterality may introduce an uncontrolled factor which may influence behavior at a choice point. In other words, if a rat has a sidedness preference, some mazes will be unusually difficult for him.

An accidental finding of Brundage's (2) at the Indiana Conditioning Laboratory disclosed the unusual fact that, in general, the reflex response that was being conditioned (in the rear foot) also involved the response of the front foot on the opposite side more often than that of the same side. There seemed to be a hint here of a hitherto unexplored functional linkage between the diagonally opposite feet. This result stimulated the present study.

Pertinent also is the observation of Kellogg, Scott, Davis and Wolf (10) that the flexion CR in dogs is a complex response and that the shifting of weight and postural readjustments, moreover, may take in a good deal of the skeletal musculature of the forepart of the body. More recent work by Davis (4) on "Set and Muscular Tension" investigated

by means of action potentials suggests that there may be a variety of tension patterns distributed in a particular "set." While Davis' research was restricted to human subjects, it has certain implications for animal work.

In a summary way, then, the few studies reviewed establish the fact that the way conditioning shall develop in a particular organism depends, in a measure, upon the immediate and past postural conditions.

A thorough search of the literature reveals the curious fact of only three instances in which both conditioned and unconditioned stimuli employed have been in the same sense department. It would seem that if both CS and US are the same, they may be more objectively measured and controlled. At the same time, they permit a simplification, as it were, of the experimental situation. At any rate, their use permits a more careful analysis of conditioned and unconditioned responses. Unquestionable, too, is the advantage of a direct comparison of the conditioned and the unconditioned response. In view of the feasibility of investigations from such an approach, it is indeed strange that practically all research has regularly involved two different sense modalities.

Statement of the Problem. The foregoing account of conditioning literature suggests that drug effects are not well understood, that the work has just begun to yield information and that it is sometimes contradictory. Except where refined methods have been ingeniously devised for highly specific study, all the experimental factors have not always been under control. A review of the literature, likewise, discloses a rare occurrence of conditioning methods employing stimuli in the same sense modality. The two or three studies mentioned above have yielded information strikingly different from that usually derived. Such a technique may be justifiably investigated *per se* for comparison with traditional methods.

The present experiment proposed, then, to investigate more precisely the postural variables noted by previous investigators. The plan was to train two groups of four dogs each in the following manner. One group would receive a conditioned stimulus shock in the right front and the other group in the left front paw. By use of the readily available shock-shock technique it would be possible to deliver an unconditioned stimulus shock to the right rear feet of all subjects. That is, the Ss would be conditioned to lift the right rear paw to a conditioned stimulus shock in the front limb. In this way, both stimuli would be the same and their responses would then be comparable. Best of all, responses to the two shock stimuli would be directly observable and no guess work would be necessary regarding its "effect." A behavioral criterion of a prescribed lift of the shocked feet could be elicited and maintained by means of an adjustable stimulus.

Such a set up warranted, as a purely incidental project, use of Nembutal as a means of furnishing a check on the effectiveness of the buzz-shock technique employed by Headlee and Kellogg (8) in their conditioning with Nembutal.

The problem, therefore, resolved itself into a four-fold investigation which aimed specifically:

1. To investigate the possibilities of the shock-shock technique for conditioning.
2. To note what effect differential postural adjustments have on rate of acquisition of the conditioned response.
3. To probe into the general nature of conditioning within the same sense modality.
4. To check on the validity of the buzz-shock method in conditioning under Nembutal.

Experimental Procedure. The experiment, conducted at the Indiana University Conditioning Laboratory, utilized eight unselected mongrel dogs supplied by an animal dealer. The procedure was to place each subject individually in a conditioning stock located in a sound-proof room with one-way vision windows. Each foot of the S was fastened to a lever which permitted the recording of foot movements upon a smoked kymograph record. Record was also made of the time of presentation of both stimuli, breathing changes, and a time line.

Such a method of stimuli presentation has been called the shock-shock technique and has consisted simply of substituting an additional electric shock for the customary buzz of the buzz-shock method without changing the unconditioned stimulus or the duration or spacing of either stimulus. The conditioned stimulus shock has consisted of a 1,000-alternating current shock of 2 sec. duration delivered to one of the forepaws. The unconditioned stimulus consisted of the usual make-break direct current shock .2 sec. in length occurring simultaneously with the last .2 sec. of the conditioned alternating-current shock. In the case of four subjects, designated the homolateral group, the conditioned shock was sent to the right front paw and the unconditioned stimulus to the right rear limb (i.e., the same side). In the case of subjects of the diagonal group, the conditioned shock was delivered to the left front paw and the unconditioned stimulus to the right rear (i.e., the diagonally opposite foot). Other features of the procedure have been published elsewhere **(8, 9, 10)**.

Training was carried out in the following manner. Each S was given a total of 400 trials, distributed in four sessions of 100 trials each spaced a week apart. Half of the trials were made under drug and the other half under non-drug (control) conditions. Four of the subjects received hypnotic doses of Nembutal in the first and third sessions and the other four in the second and fourth. This rotational plan minimized effects of order within the conditioning process. Tests of retention of the conditioned response were made prior to any training and previous to the weekly series of each succeeding session of 100 trials. Measures of frequency, amplitude, and latency of conditioned response were tabulated from which learning curves were drawn and analyzed for each S and for the two groups (homolateral and diagonal). Behavioral notes yielded data with respect to struggling, defecation and urination.

Summary of Results. The primary finding of the present experiment was that diagonally trained Ss (i.e., those stimulated in the left front and right rear feet) were more easily conditioned to make a

flexion response than were homolaterally-trained Ss (right rear and right front paws). Figure 1 readily indicates the erratic course of CR acquisition of the homolateral group as compared with the more steady rise of the curve for the diagonals. This is interpreted as being the result of contradictory responses initiated in the limbs of the homolateral

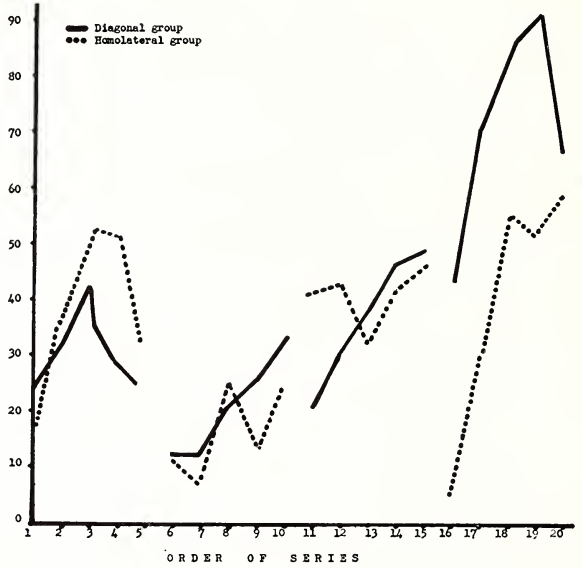


Fig. 1. Percentage frequency of conditioned responses in right rear leg of diagonal and homolateral subjects.

Ss and is in line with the Sherrington (12) claim of a functional linkage of diagonally-opposite members. In other words, the diagonally-trained dogs were administered a type of stimulation which we might consider as more "natural." It involved an easy readjustment of posture to lift diagonally opposite feet. On the other hand, the homolateral group which received stimulation entirely on one side (right rear and right front feet) had a more difficult time in acquiring the CR because of the greater disturbance and also because a facile postural readjustment in their case was prevented. Such conflicting movements have actually been observed in the protocols.

Further evidence of more favorable conditioning in the homolateral group is seen in figure 2. This shows results obtained in the retention tests given prior to training and previous to each subsequent session in which the unconditioned stimulus shock was omitted and the conditioned stimulus shock to the front foot was given alone. It will be noted that both groups show an identical start of 10% prior to any training. This is interpreted to be the result of a generalized struggle response characteristic of early training in all animals. But note the divergent results in succeeding tests. The diagonals gradually rise to a high of 37.5%

while the homolateral S decline to a low of 2.5%, again indicating more favorable conditions of the diagonal Ss.

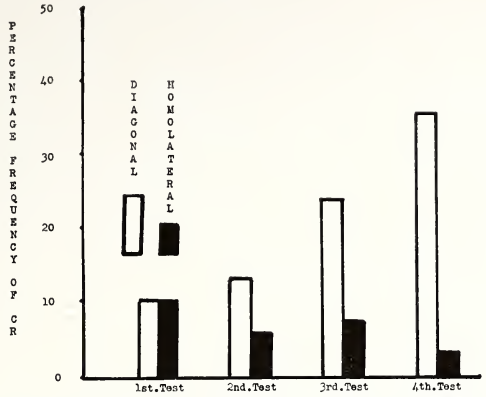


Fig. 2. Average retention of conditioned responses of right rear leg of diagonal and homolateral groups. Each retention test was given prior to any training and immediately preceding the four successive-sessions spaced a week apart.

Furthermore, it was found that there were twelve instances of urination and defecation in the homolateral Ss but only one such occurrence in the case of the homolaterals. It has been suggested by some investigators that such behavior results in emotional, disorganizing situations and may well reflect the more favorable experimental situation of the diagonally-trained group of animals.

As to drug differences, it was incidentally noted that both groups showed better conditioning under non-drug than under drug conditions. In addition, when percentage frequency curves of acquisition were drawn and compared with those drawn for the six Ss in the buzz-shock investigation of Headlee and Kellogg (8), it was found that:

(1). Rate of CR acquisition for the Diagonally trained group was superior to that of their Ss.

(2). Homolaterally trained Ss were somewhat less efficient in this respect.

(3). Under "favorable" circumstances, the shock-shock technique is superior to buzz-shock conditioning.

Summary and Conclusions. Eight unselected mongrel dogs were conditioned by means of the shock-shock technique, a method employing shock stimuli for both the conditioned and unconditioned stimuli. Four of the subjects (the homolateral group) were trained to lift the right rear foot to a shock in the *right front* paw and the other four (diagonal group) to a shock in the left front limb; i.e., the diagonals received an unconditioned shock in the right rear foot and a conditioned stimulus shock in the left front, the diagonally-opposite paw, and the homolaterals were given an unconditioned stimulus shock in the right front. Four sessions, each consisting of one hundred trials spaced a week apart and alternating drug with non-drug sessions were given each subject.

Tests of retention were made previous to the weekly series of 100 trials. Kymograph record was also made of respiration and of the lift of each foot. Measures of frequency were tabulated and analyzed and behavioral data scrutinized for significant observations.

Results showed that diagonally-trained Ss showed a more gradual and consistent acquisition of conditioned response than homolaterally-trained animals as a result of more favorable stimulating circumstances of the former group. Further proof of the superior conditionability of the diagonal Ss was evidenced in the retention tests administered both groups weekly and in the lack of evacuations and defecations for these Ss. However, both groups showed better performance under non-drug (control) than under drug conditions. As to the relative merits of shock-shock and buzz-shock conditioning, it was found that a higher level of efficiency was secured for our diagonal group as compared with Headlee and Kellogg's subjects trained by the buzz-shock method and that even our homolateral (unfavorably trained) animals are not greatly inferior. The shock-shock method is believed to recommend itself as an invaluable procedure for precise work, particularly with use of drugs, where thresholds are far from stable.

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ZOOLOGY

Chairman: T. M. Sonneborn, Indiana University

Professor R. M. Cable, Purdue University, was elected chairman of the section for 1943.

Mating reaction of double animals in *Euplotes patella*. E. Lawrence Powers, Jr., University of Notre Dame.—The double animal in *Euplotes patella* possesses two nuclear complexes, each equivalent to the complex possessed by the ordinary single animal. Mixture of the double animals with appropriate single animals results in conjugation between the two types of animals. It has been possible, therefore, to breed doubles containing nuclear complexes of varied genotypes. In many instances double animals have been produced which possess two complexes, one containing the alleles determining one mating type and the other containing the alleles determining an entirely different type (six mating types, numbered I through VI, have been described for this variety of *E. patella*). These double animals were then tested for mating type. The evidence supports the contention that in producing the mating type of E. patella each of the mating type alleles acts independently of any other mating type gene that may be present in the same nucleus.

Social organization and leadership among sheep. J. P. Scott, Wabash College.—A moving picture in color showed the daily and seasonal cycle of social life among domestic sheep. In descending order of importance, social behavior of females may be classified as allelomimetic (mutual imitation), epimeletic (care of others), fighting, sexual, and shelter seeking. For males sexual and fighting behavior are more important and epimeletic non-existent. Social dominance may be developed through any type of social behavior. In sheep the most important type of dominance is achieved through a reward—association of the mother with eating. The result is that the elder ewes become the leaders of the flock in most activities.

Growth studies as an aid in fisheries management. W. E. Ricker, Indiana University.—The age of most of the common Indiana game fish can be determined from the markings on their scales. If the populations of a given species, in different lakes and streams, be compared in respect to average rate of growth, it provides an objective measure of the suitability of each habitat for that fish; at least from the point of view of obtaining optimum production. Rate of growth is determined principally by (1) food available, and (2) the abundance of the fish in question and of its competitors. Pond experiments have shown a very nice reciprocal relation between growth rate and abundance. At any given level of available food, the total weight of fish produced in a season varies little, over quite a wide range of population densities. In theory, a standard optimum range of growth rates could be set up, with which

the observed growth in natural waters could be compared. Information necessary for such a standard is, however, not yet available for any species of fish in Indiana.

Respiration of the reptilia as influenced by the composition of the inspired air. D. E. STULLKEN, W. C. RANDALL, and W. A. HIESTAND, Purdue University.—Fourteen species of reptiles representing the four major orders of the class *Reptilia* were used for studies of normal breathing and the effects of hypoxia, hyperoxia, and hypercapnia. Respiratory movements were recorded by the use of appropriately constructed plethysmographs designed to accommodate the particular reptile. An exception was made in the case of the alligator whose respiratory movements were recorded by means of an accordion type pneumograph. Plethysmographs and pneumograph communicated with a recording tambour writing on a long paper kymographion. Gases of different composition were applied by way of special hoods designed to fit loosely over the reptiles' heads. The gaseous composition of the air stream inside the hood was checked by a Haldane apparatus. Amplitude and rate of respiration were recorded for each of the four orders for various mixtures of gases.

A comparison of the role of the afferent vagal fibers in respiratory control in birds and mammals. W. A. HIESTAND and W. C. RANDALL, Purdue University.—A modern concept of respiratory regulation must take into consideration at least two modifying influences affecting the behaviour of the lower, so-called *apneustic center*. The primary function of the apneustic center is that of producing a maintained inspiration. It is apparent that the apneustic center in vertebrates lower than the homoiotherms is the primary center and that the respiration of these animals is essentially of the apneustic type. Such animals lack an ability to breathe rapidly with the possible exception of the small lizards. The later phylogenetic development of higher centers seems expressly for the purpose of modifying the slow apneustic rhythm. The location of such higher centers has been shown to be approximately at the level of the pons, or even the higher region of the hypothalamus. That the vagal nerves contain inspiratory-inhibitory or expiratory-excitatory fibers or both has been indicated by various findings accumulated since the original investigations of Hering and Breuer. Rabbits show a change to a slower respiratory pace after section of one vagus, which becomes still more profound with section of the second. Birds after vagotomy are barely able to breathe. The respiration rate of the common fowl may drop to as few as four strokes per minute after bilateral vagotomy. In the panting mammal, section of either or both vagi has no effect on respiratory rhythmicity which indicates that the vagi are inactive during mammalian panting. However, in the bird (domestic fowl) the vagi are necessary for panting, for if they are both sectioned the panting immediately is lost and is replaced by slow non-panting rhythm. If only one vagus is sectioned during panting no change in rhythm results. If instead of section of the vagi, cocainization is used, the effects will be the same, i.e. when both vagi are incapacitated panting ceases.

Studies on Monogenetic Trematodes. IX. Host specificity of Pomoxis Tetraonchinae. J. D. MIZELLE, D. R. LAGRAVE, and R. P. O'SHAUGHNESSY, University of Notre Dame.—Mizelle (1936, '38) repeatedly observed four species of Tetraonchinae (*Cleidodiscus capax, C. uniformis, C. longus,* and *C. vancleavei*) on the gills of white crappies (*Pomoxis annularis*) taken from Illinois and Oklahoma waters. Of these, only two (*C. capax* and *C. vancleavei*) were recovered from the gills of black crappies (*P. nigromaculatus*) which were examined during the same investigation. Anxious to determine whether or not all four species of the parasites in question might possibly occur at times on the black crappie, Mizelle examined additional hosts from Reelfoot Lake (Ridgely, Tenn.) and the Mississippi River in Illinois, and in no case did *C. longus* or *C. uniformis* occur on the gills of the black crappies but did occur regularly on the gills of white crappies along with the other two species listed for this host.

Another case of intestinal myiasis. MARCUS W. LYON, JR., South Bend Clinic, and JOHN D. MIZELLE, University of Notre Dame.—The accumulated data available at present indicate that many ingested fly larvae do not survive the environmental conditions of the digestive tract while others do and produce intestinal myiasis of different degrees of intensity. The present case involves larvae of *L. sericata* and an undetermined species of *Sarcophaga* which were identified by Drs. Herms and Stewart of the University of California. A twenty-three-year-old housewife living in an unscreened house in the residential part of South Bend, Indiana, consulted the South Bend Clinic on several occasions for various complaints. In 1938, she complained of a burning sensation on urination. At that time her appetite was good and her bowels were regular without the use of laxatives, but she occasionally became nauseated and vomited after eating. In July, 1940, her urinary condition became worse and necessitated her getting up at night. On July 5, 1941, the patient submitted a stool for examination. It was of normal color and consistency and negative except for a few threads (10-12 mm. long) of definite plant origin. On August 5, 1941, she submitted another stool of the same general nature except that it contained many large dipterous larvae (about 10 mm. by 1½ mm. in diameter). The present case, characterized by the symptoms of nausea, vomiting, and abdominal distress is conspicuous by the absence of diarrhea which is generally one of the chief symptoms of intestinal myiasis. The history regarding the urinary trouble is interesting since Chandler (1941) recorded a case of urinary myiasis with essentially the same symptoms.

Noctuidae of Steuben County. G. S. RYAN, Angola.—This paper consists of records of the family Noctuidae which cover the period from May 1, 1937, to October 1, 1941. The records are based on sixty-two species and represents thirty-seven genera. Some of the specimens are rare, and others are common. The data cover the periods that the moths are in flight.

Acquired Immunity to a Specific Antibody and Its Inheritance in Paramecium aurelia

T. M. SONNEBORN,* Indiana University

An animal infected with a pathogenic microorganism responds, as is well known, by the development in its blood of an antibody which acts specifically on the invading parasite. This is the natural defense mechanism of the animal against injury by the parasite. Many researches (1) during more than 30 years indicate the less well known fact that the parasite may respond to the host's antibody by developing heightened resistance or complete immunity to it. Such a response appears as an increased virulence of the pathogenic organism and becomes an important medical problem. The mechanism of this apparent increase in virulence is not thoroughly understood and three interpretations have been suggested: (1) The initial infection included more than one strain of pathogens and the initially predominant form alone was killed off by the antibody, thus permitting another strain to develop predominance; this is then a theory of selection. (2) The antibody produced by the host acts as a mutation inducing agent and produces mutations altering the antigenic properties of the parasite. (3) The antibody produces changes in the antigenic properties of the parasite, but these are not true mutations; they are merely long-lasting modifications or temporarily inherited changes which invariably revert to the original condition. The third interpretation is so fundamentally out of harmony with knowledge of heredity in other organisms that one or the other of the first two interpretations has been most generally accepted by workers in this field. However, the pathogenic organisms are unsuitable for critical analysis of the problem because (1) purity of the strain is difficult to establish in pathogenic organisms; and (2) the absence of sexual processes makes impossible genetic tests of the mutation hypothesis.

I have therefore attempted to analyse the problem in *Paramecium aurelia*, a single-celled animal particularly favorable for such studies. A race known to be entirely pure (homozygous) for all its genes was injected into rabbits. The antibody formed in the rabbit's blood is specifically active on the race of paramecia used for the injections even when the antiserum is diluted 1 part to 4,000 parts of salt solution. Its activity consisted in quickly paralyzing the paramecia and in killing them when applied in concentrations greater than 1:1000. Although occasional individuals of this race of paramecium show temporary increases in resistance to the antiserum, none of these differences persisted for even a single day during reproduction by fission. The race is thus hereditarily uniform and the first hypothesis, selection, cannot be invoked as an explanation of acquired immunity.

* Contribution No. 315, Department of Zoology, Indiana University.

When the temporarily resistant paramecia were subjected to the antiserum they acquired complete immunity to the antiserum: they were no longer affected by even undiluted antiserum. Further, this induced immunity was inherited during reproduction by fission in culture media entirely free from antiserum. In some lines of descent the immunity was suddenly and completely lost after a short period (a week or so; 25 to 30 cell generations); in others it lasted for various longer periods, still existing in some after a period of more than 75 days of rapid multiplication (more than 279 cell generations). In all immune cultures, however, the hereditary immunity was invariably lost suddenly and completely after fertilization. This result occurred regardless of the combinations brought together at fertilization: in crosses of immune by susceptible cultures; in crosses of immune by reverted cultures; in crosses between two different immune cultures; and in self-fertilization within a single immune culture. These results demonstrate that the acquired immunity is not an ordinary persistent mutation, but is only temporarily inherited for long periods during vegetative reproduction, as maintained by the third hypothesis above.

Finally it was demonstrated that the loss of immunity was not due to induction of reverse mutations by the serum-free culture medium, for it also occurred in the absence of fertilization in media containing dilute antiserum. When immune cultures underwent fertilization in this dilute antiserum culture medium, many lost their immunity at once; but others retained it for variable periods, as in the original inductions.

This study demonstrates that, in Paramecium, the persistence of acquired immunity to a specific antibody is due neither to selection nor to ordinary mutations. It is a case of *temporary* though long inheritance of an acquired character. This is a form of inheritance not recognized by modern, generally accepted canons of genetics, but was extensively studied by its discoverer, Jollos (2). Further investigations designed to bring such temporary inheritance under experimental control will doubtless be of great value both theoretically and in the control of infectious disease.

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Preliminary Report on Mosquito Repellents

ERNEST RICHMAN and H. O. DEAY, Purdue University

During the season of 1942 certain proprietary mosquito repellents and various chemical combinations were tested at Lafayette, Indiana, to determine their efficacy in repelling mosquitoes.

Materials Tested: Of the repellents tested the following five gave the most promising results: Repellent 1, which consisted of one part

Fig. 1. Biting frequency per minute was determined by exposing untreated arm for five minutes to mosquito attack.

oil of cedar wood, two parts oil of citronella, and two parts spirits of camphor; repellent 2, which consisted of four parts diethylene glycol monoethyl ether acetate and one part of castor oil; repellent 3, which consisted of four parts diethylene glycol monoethyl ether and one part

of castor oil; repellent 4, which consisted of one part oil of eucalyptus, one part oil of lavender, one part oil of thyme, one part oil of pennyroyal, one part oil of rosemary, and two-thirds part linyl acetate; repellent 5, which was *Sta-Way*, a proprietary compound. No active ingredients were given on the label of this material. The inert ingredients are alcohol, 28 per cent, and corn oil, 7 per cent.

Methods and Procedure: Six subjects, who varied in their susceptibility to mosquito attack, were used to test the efficiency of the repellents. The reactions of a number of people as to whether the odor of each of the repellents was pleasing, neutral or objectionable were obtained.

Tests were also made to determine if the repellents had an irritating effect on the skin and if they stained or bleached various kinds of cloth.

Specimens of the mosquitoes present at each test were collected. It was found that there was always two or more species present, the most common of which was *Aedes vexans*.

The procedure, which followed that used by Granett* rather closely, was as follows:

Fig. 2. The repellent was applied to arm with a rubber-handled glass rod.

1. At the beginning of the test an untreated arm or leg of the subject was exposed for five minutes so as to determine the biting frequency per minute of the mosquitoes before the application of the repellent (Fig. 1). No results are reported here in which the biting frequency was less than four per minute. 2. One cc. of the repellent to be tested was spread evenly by means of a rubber handled glass rod on the arm, or two cc. on the leg of the subject (Fig. 2). 3. The treated arm or leg was exposed continuously to the attack of the mosquitoes throughout the test while the rest of the body was kept covered except that an untreated leg or arm was exposed for two minutes at 10 minute intervals

* Granett, Philip. Studies of Mosquito Repellents. Jour. Econ. Ent. **33**(3); 563-572. 1940.

to determine the biting frequency during the process of the test. It was found that a common bee-veil was effective in protecting the face, head and neck against the attack of the mosquitoes (Fig. 2). 4. The lapse of time between the exposure of the treated arm or leg and the first definite mosquito bite was recorded as the repellent time. The time between the first and second bite was also recorded.

Results: The repellent time of each of the five repellents reported on at this time is shown in figure 3.

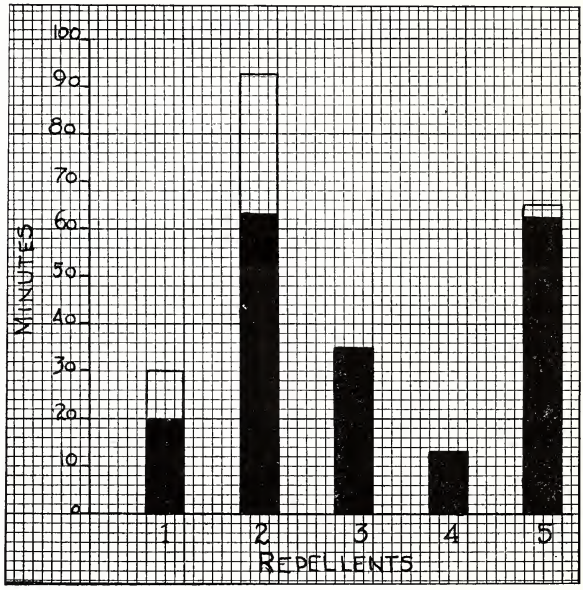

Fig. 3. Graph showing repellent time of various repellents. The black area shows the average repellent time.

Repellent 1 repelled the mosquitoes for 20 minutes on the average and for a maximum of 30 minutes not only from the treated surface of the body, but also from the immediate vicinity of the subject for a distance of five to ten feet. This material stained the least of any of those tried. It had no irritating effect on the skin, nor was its odor objectionable, especially when used in the open.

Repellent 2 repelled for 63 minutes on the average and for a maximum of 92½ minutes. It was nonirritating and had but a slight odor. However, it repelled the mosquitoes only from the surfaces where it was applied. Although not as consistent in its repellent time as Repellent 5, its maximum repellent time was 27 minutes longer.

Repellent 3 was effective for 35 minutes but it protected only the parts where it was applied. It stained only slightly and had no irritating effect on the skin. Its odor was pleasing to most people.

Repellent 4 repelled mosquitoes for 13 minutes, making it the least effective of the mixtures reported here. It protected only the treated areas and has a rather nauseating odor, especially when used in inclosed areas.

Repellent 5 repelled for 62 minutes on the average with a maximum repellent time of 65 minutes. It was the most consistent in its results of all of the repellents used, the range of repellent time on three subjects was from 56 to 65 minutes. However, it protected only the areas treated and stained more than any of the above preparations. It caused a slight irritation to the skin of three out of seven subjects, especially when applied to the face.

Although all of the mixtures used stained somewhat, these stains were in all cases removed by either a cleaning fluid (carbon tetrachloride) or by soap and water.

Intestinal Parasite Infections of 203 University Freshmen

William Hugh Headlee and William B. Hopp, Purdue University

Introduction

This paper presents the results of another of a series of studies that have been made by the senior author, or under his direction, during the past six years in an effort to accurately determine the incidence of human intestinal parasite infections in the general Hoosier population, and to evaluate their importance in relation to public health. These studies have included residents of both urban and rural areas, university students and two large groups of individuals confined to State Hospitals for the Insane (Headlee, 1937, 1939, 1940, 1942a, 1942b; Headlee and Hopp, 1940; Headlee, Kmecza and Cable, 1939; Hopp, 1940; Kmecza, 1939).

In making these studies an attempt has been made to examine a representative group of individuals of the state, including persons from a large number of localities and from different economic and social levels of the population. Examination of Purdue University students has helped to achieve these ends, since a large number of these students are residents of Indiana and represent a general type in reference to economic and social status, although there are considerable individual differences. Accordingly, at the beginning of the summer term of 1942, examinations were made of a number of incoming freshmen men with the aim of adding to our information concerning the intestinal parasite infections among residents of Indiana, as well as to gain information that would aid in determining the need for attention to these organisms in relation to student health.

Materials and Methods

The data presented in this paper were obtained by the microscopic examination of fecal specimens. By this examination both the cysts and trophozoites of protozoa and the eggs of helminths could be detected. Two hundred and seventy-five men of the incoming freshman group were contacted individually as they took their entrance physical examination. Each person was given a cardboard container and requested to submit a stool specimen for examination, this specimen to be brought to the laboratory on an assigned date, during the months of May and June.

The stool specimens were examined in the laboratory by means of a combination of the direct smear method and the zinc sulfate centrifugal flotation technic (Faust et al., 1939), the latter being a concentration method.

Presentation of Data

A total of 203 students, or 74.0 per cent of those contacted, submitted stools for examination. Only one stool from each individual was examined, but it was examined by the two methods mentioned above.

All of the students examined were males, ranging in age from 16 to 48 years. One hundred and ninety-three, or 95.1 per cent, were in the 16-20 age-group, 8 were in the 21-25 age-group, 1 was 26 yrs. of age and 1 was 48 yrs of age. Of the total examined, 55 or 27.1 per cent, were infected with protozoa, helminths or both protozoa and helminths. Six, or 10.9 per cent, of these infected individuals were harboring one or more species of parasite of either proved or probable pathogenicity. The species of parasites found with their percentage incidences were as follows: *Endamoeba histolytica*, 1.0; *Endamoeba coli*, 18.2; *Endolimax nana*, 11.8; *Iodamoeba* bütschlii, 0.5; *Giardia lamblia*, 1.5; *Chilomastix mesnili*, 0.5; *Necator* (hookworm), 0.5, and *Enterobius vermicularis* (pinworm), 0.5. The hookworm and pinworm infections were harbored by the same individual. A detailed analysis of the data is presented in Table 1, consideration being given to the residents of Indiana as a group. The data would seem to indicate that students with an established residence outside of Indiana have a lower incidence of intestinal parasites, and fewer species of parasites. The number of students represented is too small to warrant a final conclusion of this kind.

TABLE 1.—Intestinal Parasite Infections among 203 University Freshmen

Age	State of Indiana 16-48		Other States 16-25		Total 16-48	
	No.	%	No.	%	No.	%
Endamoeba histolytica	2	1.3			2	1.0
Endamoeba coli	29	19.3	8	15.1	37	18.2
Endolimax nana	17	11.3	7	13.2	24	11.8
Iodamoeba bütschlii	1	0.7			1	0.5
Giardia lamblia	3	2.0			3	1.5
Chilomastix mesnili	1	0.7			1	0.5
Necator	1	0.7			1	0.5
Enterobius	1	0.7			1	0.5
Total infected with protozoa	43	28.7	12	22.6	55	27.1
Total infected with helminths	1	0.7			1	0.5
Total infected with both protozoa and helminths	1	0.7			1	0.5
Total infected with either or both protozoa and/or helminths	43	28.7	12	22.6	55	27.1
Total examined	150		53		203	

The students examined were residents of twelve states and the District of Columbia. One hundred and fifty, or 73.9 per cent were from the state of Indiana, 43 of the 92 counties of this state being represented. Thirty were from Tippecanoe County, 24 from Marion County, 11 from St. Joseph County, with lesser numbers from the remaining counties,

21 being represented by only one individual each. Of the states other than Indiana, Illinois had the largest representation, this being 27 students, or 50.9 per cent of all students outside of Indiana that were examined. In Table 2 data is presented indicating the number of students examined from each state, its per cent of the total examined and of those examined outside Indiana.

TABLE 2.—Data on the Residence of Students Examined.

State	No.	Per Cent of Total Examined	Per Cent Outstate Exams.
Indiana	150	73.9	
Illinois	27	13.3	50.9
Ohio	8	3.9	15.1
Kentucky	4	1.9	7.5
New York	3	1.5	5.7
Michigan	2	0.9	3.8
Mississippi	2	0.9	3.8
Wisconsin	2	0.9	3.8
Washington, D.C.	1	0.5	1.9
Kansas	1	0.5	1.9
Massachusetts	1	0.5	1.9
New Jersey	1	0.5	1.9
Oklahoma	1	0.5	1.9
Total examined	203		

Discussion and Conclusions

No attempt will be made at this time to compare the data of the present survey with that obtained by similar studies of students of universities or schools outside of Indiana. Organisms of proven pathogenicity were harbored by 3, or 5.4 per cent, of those infected, while an equal number of individuals were infected with parasites of questionable pathogenicity. The two infections of *Endamoeba histolytica* were not producing demonstrable symptoms, but they should not be ignored as a source of infective material that will aid in the dissemination of the organism. Neither should these infections be ignored as a potential if not actual detriment to the individual harboring them, since lesions are produced even though symptoms may not be manifest.

There is no indication that the hookworm infection noted in this study was a native infection, since the individual harboring it had traveled considerably. Other surveys indicate that the hookworm infection may be native to Indiana. The incidence of the pinworm is rather low, and it is expected that the incidence would be higher if other methods of diagnosis were used (Headlee, 1942). Even in a similar group (Headlee, 1940) when less efficient diagnostic methods were used, the incidence of

this parasite was 1.9 per cent as compared to the 0.5 per cent of the present study.

The data obtained from the examination of university students prior to September, 1939 (Headlee, 1940) are presented in Table 3 along with the percentage incidence data of the present survey in such a manner that they can be compared. These two groups have been combined and the percentage incidence of the various parasites has been calculated, based on the examination of 416 students. Some parasites were represented in the 1940 survey that were not found in the present study. In the 1940 study the incidence for the various parasites was equal to or higher than the incidence for the same parasite in the present study.

TABLE 3.—Comparison of Data (Incidence Shown in Per Cent) of 1940 and 1942 Surveys; Data on Combined Surveys.

	1940	1942	Total
E. histolytica	2.8	1.0	1.92
Endamoeba coli	19.7	18.2	18.99
Endolimax	30.5	11.8	21.39
Iodamoeba	1.4	0.5	0.96
Giardia	2.3	1.5	1.92
Chilomastix	0.5	0.5	0.48
Ascaris	0.9		0.48
Trichuris	0.9		0.48
Necator	0.5	0.5	0.48
Enterobius	1.9	0.5	1.20
Hymenolepis	0.5		0.24
Tot. Inf. Protozoa	42.7	27.1	35.09
Tot. Inf. Worms	4.7	0.5	2.64
Total Infected	45.5	27.1	36.54
Total Examined	213	203	416

Although the incidence of pathogenic parasite infections among individuals of this group is relatively low, the data presented lend further support to previous studies, and indicate that parasite infections are a reality in the temperate regions, and, here as elsewhere, they should receive specific attention as factors and etiological agents of disease.

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The Indian Rat Flea, *Xenopsylla cheopis*, in Indiana

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The presence of *Xenopsylla cheopis* (Rothschild), the so-called Indian rat or plague flea, in the United States has been recognized for many years. It was reported first from coastal cities where it was introduced presumably by rats escaping from ships. It was first recorded from an inland locality by Wallace (1925) who found it on rats in Indianapolis. Since that time, the species has been reported from other midwestern localities. It was found on rats at Ames, Iowa, by Roudabush and Becker (1934), and Owen (1936) reported a severe infestation of an attendant in a dairy barn at the University of Minnesota. Ewing and Fox (1938) identified as *X. cheopis* fleas biting workers in an office at Youngstown, Ohio, and also reported that this species had been taken in an elevator at Urbana, Illinois. Trembley and Bishopp (1940) reported its appearance at Nashville, Tennessee, and Runner (1941) found it in residences and university buildings at Columbus, Ohio. Grundmann, Boles and Ackert (1941) have shown that the plague flea extends westward as far as Manhattan, Kansas. This flea has been regarded as a tropical and subtropical species which probably could not overwinter in the northern states but the observations of Ackert, Boles and Grundmann (1941) indicate that this is not the case.

Since 1935, wild rats have been killed from time to time on the Purdue campus and in the city of Lafayette and examined for parasites. Fleas on these rats were preserved and later used by students in parasitology in preparing whole mounts of arthropod material. Until 1939, *Nosopsyllus fasciatus* and a few *Ctenocephalides felis* were the only fleas found on these rats. In the spring of that year, however, rats killed in one of the animal houses on the campus harbored plague fleas exclusively. Since Wallace found *X. cheopis* in Indianapolis 17 years ago, this species probably spread to Lafayette long before we detected it.

During the writer's absence from the university in the summer of 1941, wild rats gained entrance to a room containing albino rats and mice. Upon returning in September, he found the albino rats suffering from extremely heavy infestations with plague fleas. Every rat had hundreds of them, was emaciated, and obviously suffered from loss of blood; several animals died before the infestation was brought under control. Curiously enough, neither albino mice, only a few feet away, nor persons entering the room were attacked to a noticeable degree. Although this room has been cleared of fleas, the infestation still persists in other parts of the building to which wild rats have access. In October, 1942, mixed infestations of *X. cheopis* and *Ctenocephalides felis* were noted on albino rabbits kept in the building.

The most disturbing aspect of the widespread occurrence of *X. cheopis*, particularly under war-time conditions, is the known ability of

this flea to transmit *Pasteurella pestis*, the plague bacillus. While bubonic plague has appeared sporadically in American coastal cities, it has in no case persisted for more than a few years at most, probably because of measures taken to segregate patients and prevent spread of the disease. One form of plague, the so-called sylvatic type, has become firmly established in wild rodents of the western states which, according to Eskey and Haas (1937), include California, Oregon, Washington, Idaho, Utah, Nevada, Arizona, Montana, Wyoming, and New Mexico. The disease apparently has spread over this area from original focal points on the West Coast where it was first observed in 1900. Meyer (1939) reported that 24 species of rodents may be naturally infected with sylvatic plague. It seems that this lack of host specificity and the widespread distribution of susceptible rodents would favor spread of the disease; Grundmann, Boles, and Ackert (1941) have pointed out that it is already east of the chief natural barrier, the Great Divide.

In view of the extent of sylvatic plague among rodents, surprisingly few cases of human plague have been reported; the fatality rate among these cases has been high, however. They have been attributed in most instances to handling infected rodents rather than to the bites of fleas. The various species of fleas seem to differ considerably in their ability to transmit plague. Although viable bacilli may be voided in the feces, the effectiveness of a flea in transmitting the disease depends apparently on the extent to which the digestive tract becomes blocked with plague bacilli which may be regurgitated when the flea attempts to suck blood. *Xenopsylla cheopis* is believed to be the most effective vector of the disease. Since this species apparently is not present in many localities where sylvatic plague of rodents is established, it may be that the rarity of human cases is due largely to the absence of effective insect vectors. In that event, further spread of sylvatic plague toward the east and *X. cheopis* westward may constitute a serious menace.

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An Annotated List of the Ants of Indiana

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During the past few years, the writer has been interested in a study of the ants of Indiana and has been able to collect records of some 92 species, subspecies and varieties known to have been taken in the state. Insomuch as the only list of Indiana ants, published as such, to have appeared previous to this date contained only 42 known species and appeared over 25 years ago, it is felt that perhaps a more up to date list would be of interest to those engaged in the study of this family.

Dr. Wm. Morton Wheeler (1916)[1] published the first list of Indiana ants, mentioned above, together with notes on their habits and habitat, based on material collected by Dr. W. S. Blatchley, whose collection is now a part of the Purdue University collection. The writer's work includes Dr. Wheeler's list, and many of his notes on habits of the various species are used. To Wheeler's species has been supplemented new records from the writer's collections and from material taken by numerous other collectors[2] as well as specimens present at Purdue University.

Of the species taken by the writer, 19 were found which were not included in Wheeler's paper. Records of 14 additional species taken in the state were furnished by Dr. Mary Talbot (1934), who made a study of the ants of the Chicago region and Turkey Run State Park, Parke County, in 1934. Dr. M. R. Smith submitted to Prof. J. J. Davis a list of ants known to be in Indiana in 1937, which included 12 species not mentioned by Wheeler nor included in Dr. Talbot's or the writer's collections. Two additional species were later reported by Dr. Smith; two species described by Kennedy and Dennis (1937) from Ohio County in 1937; and a mound-building ant taken by P. T. Ulman and A. W. Trippel in 1942 complete the list of 92 ants having been found in the state.

[1] Dates refer to literature cited.

[2] The writer wishes to express his appreciation to the following persons who have assisted him in the preparation of this paper: To Dr. C. H. Kennedy of the Dept. of Zoology and Entomolgy, Ohio State University, who kindly assisted in the selection of reference material and furnished specimens of Indiana species; to Dr. M. R. Smith, Associate Entomologist of the Bureau of Entomology and Plant Quarantine, who checked many of the writer's identifications and supplied him with a list of Indiana ants; to Dr. Neal A. Weber of the University of North Dakota, who generously checked the writer's identification of species in the Genus *Myrmica;* to Dr. Mary Talbot of Lindenwood College, St. Charles, Missouri, who assisted materially in increasing the list of known Indiana ants by furnishing records and specimens of 14 new species and varieties; to Dr. Wm. Creighton of Harvard University, who offered much helpful information concerning the species described by Say in 1836; and to many friends who collected specimens in various parts of the state.

Special appreciation is gratefully extended to Dr. H. O. Deay of Purdue University, under whose guidance this paper was written, for his helpful advice and assistance.

The county has been chosen as the recording unit, records having been made from 56 counties.

A list of 56 species, subspecies and varieties, not as yet recorded from Indiana but which are undoubtedly present in the state is appended. Since many species are known to occur which would hardly be expected to be found here, this list is undoubtedly too abbreviated and it is likely that only a relatively small percentage of ants actually occurring in Indiana has thus far been recorded.

FAMILY FORMICIDAE

Subfamily Ponerinae

This is the only subfamily of Formicidae which comprises unmistakably primitive and generalized forms. Its members form a connective link from the rest of the Hymenoptera to the members of the higher subfamilies of Formicidae and exhibit the oldest existing expression of social life among the ants. Members of this subfamily are, for the most part, rare and live in situations where high moisture content is a constant factor.

Genus *Stigmatomma* Roger, 1859

Stigmatomma Roger, Berlin Ent. Zeitschr., 3:225, 1859.

1. *Stigmatomma pallipes* (Haldeman, 1844).
   Typholopone pallipes Haldeman, Proc. Acad. Nat. Sci. Phila., 2:54, 1844.

A medium sized brown ant which nests in small colonies in rich, damp woods, under stones, leaf mold, and sometimes under logs. The species is rather rare.

Genus *Proceratium* Roger, 1863

Proceratium Roger, Berlin Ent. Zeitschr., 7:171, 1863.

2. *Proceratium silaceum* Roger, 1863.
   Proceratium silaceum Roger, Berlin Zeitschr., 7:131-214, 1863.

A small brown or reddish ant rarely taken abundantly. *P. silaceum* and its varieties are very primitive and possess little tolerance for variations in habitat. It is reported to nest only in well decayed logs which are large enough to retain moisture and when situated where moisture is plentiful and constantly maintained.

A species not listed by Wheeler (1916), a single worker was collected by Blatchley in Crawford County and determined by Dr. Mary Talbot.

Collection Locality: Crawford County.

References: Dennis (1938); Kennedy and Talbot (1939).

3. *Proceratium silaceum rugulosum* Wheeler, 1915.
   Proceratium silaceum rugulosum Wheeler, Bull. Amer. Mus. Nat. Hist., 34:390, 1915.

This subspecies has the same habits as the typical variety.

Collection Locality: Crawford County.

References: Dennis (1938); Kennedy and Talbot (1939); Wheeler (1916).

Genus *Ponera* Latreille, 1805

Ponera Latreille, Hist. Nat., 13:257, 1805.

4. *Ponera coarctata* Latr. *pennsylvanica* Buckley, 1866.
   Ponera pennsylvanica Buckley, Proc. Ent. Soc. Phila., 6:171, (1866) worker; Emery Zool. Jahrb. Syst., 8:267 (1894) all castes; Wheeler, Biol. Bull., 2:44, (1900) all castes.

A small black or dark brown slender species with vestigial eyes. The writer found this species most common on dead leaves of the forest floor and under the bark of decaying trees.

Collection Localities: Clinton, Jefferson, Lake, Posey and Washington counties.

Reference: Wheeler (1916).

Subfamily Dorylinae

The subfamily Dorylinae is composed of tropical and subtropical species, known as "driver" or "visiting" ants. The former inhabit tropical Africa and Asia, the latter, the warmer climates of America. Only one species of this subfamily is known to occur in Indiana.

Genus *Eciton* Latreille, 1804

Eciton Latreille, Nouv. Dict. H. N., 24:179, 1804.

5. *Eciton* (*Acamatas*) *schmitti* Emery, 1894.
   Eciton schmitti Emery, Zool. Jahrb. f. Syst., 8:258-259, 1894.

This medium sized, reddish brown ant, although a southern species, was reported to be present in Indiana by Dr. M. R. Smith, who included it in his list of Indiana ants submitted to Professor J. J. Davis of Purdue University. No collection locality nor data are known to the author.

Members of this genus are "visiting ants", traveling in huge armies, attacking many insects and even large snakes.

Reference: Wheeler (1910).

Subfamily Myrmicinae

The subfamily Myrmicinae includes among its members the harvesting ants, which depend to a large extent on seeds of grasses and other vegetation for their livelihood.

Genus *Myrmecina* Curtis, 1829

Myrmecina Curtis, Brit. Ent., 6:265, 1829.

6. *Myrmecina graminicola americana* Emery, 1894.
   Myrmecina latreilli subsp. *americana* var. *brevispinosa* Emery, Zool. Jahr. Abth. f. Syst., 8:271, 1894.

A small dark, closely sculptured ant with habits resembling those of the genus *Proceratium*. Wheeler reports this a rare species with colonies consisting of fewer than 25 workers. Both Dennis (1938) and Miss

Talbot (1934) state that nests found in logs were generally in the center of well decayed wood. It has the habit of feigning death when disturbed.

Collection Locality: Crawford County.

References: Dennis (1938); Talbot (1934); Wheeler (1916).

Genus *Monomorium* Mayr, 1885

Monomorium Mayr, Verh. Zool.-bot. Ges. Wien, **35**:452, 1885.

7. *Monomorium pharaonis* (Linnaeus, 1768).
   Formica pharaonis Linnaeus, Syst. Nat., **12**:963, 1768.

This tiny pale yellow ant is easily distinguished from the other species of the genus found in Indiana by its color and slightly smaller size but it is often confused with *Solenopsis molesta* (Say) or "thief ant" as both invade kitchens and often become serious pests.

Although this "tiny red ant" or Pharaoh's ant is reported as extremely common and general in its distribution, Wheeler failed to list it as an Indiana species in 1916, and no specimens from Indiana were present in the Purdue University collection in 1939. Furthermore, ants taken from homes in several localities during the summer of 1938 all proved to be the *Solenopsis* species. Since that time, however, the writer has taken the species several times in Marion County but is inclined to believe that *Solenopsis molesta* deserves the credit for much annoyance charged to *M. pharaonis*.

Collection Locality: Marion County.

8. *Monomorium minimum* (Buckley, 1867).
   Myrmica (*Monomorium*) *minima* Buckley, Proc. Ent. Soc. Phila., 7:335-350, 1867.

This tiny, slender, black ant nests in the ground, trees, rotten logs, and houses.

Workers are fond of sweets and are quite often found in houses. Those on the outside feed on the excreta of plant lice, the secretions of extra-floral nectaries and dead insects.

Collection Localities: Harrison, Martin, Posey, Tippecanoe and Washington counties.

References: Dennis (1938); Talbot (1934); Wheeler (1916).

Genus *Solenopsis* Westwood, 1841

Solenopsis Westwood, Ann. Mag. Nat. Hist., **6**:86, 1841.

9. *Solenopsis molesta* (Say, 1836).
   Myrmica molesta Say, Boston Jour. Nat. Hist., 1:293, 1836.

This minute yellow species nests either in wood or in the ground. The writer found it very common in corn fields. Although *S. molesta* lives in independent formicaries, it is very commonly found living in the walls separating the galleries in the nests of larger ants. In those situations it steals food and devours larvae or pupae of the other ants and rightly deserves its reputation as a "thief ant".

As a pest in households, it is probably more destructive than the Pharaoh's ant, *Monomorium pharaonis*, although it does not commonly

nest in houses and thus is more readily controlled than *M. pharaonis* which takes up living quarters in the house itself.

Collection Localities: Clark, Crawford, Fountain, St. Joseph, Tippecanoe and Washington counties.

References: Dennis (1938); Wheeler (1916).

Genus *Pheidole* Westwood, 1841

Pheidole Westwood, Ann. Mag. Nat. Hist., 6:87, 1841.

10. *Pheidole pilifera* Roger, 1863.

Pheidole pilifera Roger, Berlin Ent. Zeitschr., 7, 1863.

A reddish-brown dimorphic ant, the major workers possessing extraordinarily large heads. The writer took this species several times, always (with one exception) from gravelly situations, namely, from gravelly hillsides, gravel pits, sandy banks and gravel roads. In one instance, it was taken from a decayed stump. *P. pilifera* is a true harvesting ant, storing its nest with seeds of grasses and other plants. Wheeler believed that the large-headed workers function as seed crushers.

Collection Localities: Martin, Tippecanoe and Washington counties.

Reference: Dennis (1938).

11. *Pheidole bicarinata* Mayr, 1870.

Pheidole bicarinata Mayr, Verh. Zool.-bot. Ges. Wien, 20:989, 1870.

This small reddish-brown species was taken by Dr. Mary Talbot during her work on the ecological distribution of ants in the Chicago region. It was taken in open craters in the sand dunes and she reported the workers foraging in open files.

The species is much more rare than *P. pilifera.*

Collection Localities: Lake and Porter counties.

Reference: Talbot (1934).

Genus *Crematogaster* Lund, 1831

Crematogaster Lund, Ann. Sci. Nat., 27, 1831.

12. *Crematogaster* (*Acrocoelia*) *lineolata* (Say, 1836).

Myrmica lineolata Say, Bost. Jour. Nat. Hist., 1:290, 1836.

One of the most common of our Indiana ants, the writer found this species on practically every collecting trip. It usually nests in wood but may sometimes be found under stones. It is fond of sweets and can often be found attending aphids and similar insects. The workers construct characteristic carton partitions or cells in their nest or over aphids and coccids on plants. They have a disagreeable odor and carry their triangular gaster over their thorax with the tip directed forward. Because of this habit they have been called "acrobat" ants.

Collection Localities: Clark, Knox, Lake, Lawrence, Monroe, Montgomery, Pike, Posey, Pulaski, Putnam and Tippecanoe counties.

References: Talbot (1934); Wheeler (1916).

13. *Crematogaster* (*Acrocoelia*) *lineolata cerasi* (Fitch, 1854).
Myrmica cerasi Fitch, Trans. N.Y. State Agr. Soc., **14**:835, 1854.

Although not as common as the typical species, this ant was taken by the writer on several occasions. It is a yellowish form of the above species.

Collection Localities: Crawford, Fountain, Kosciusko, Knox, Lake, Marshall, Martin, Rush, Starke, Tippecanoe and Washington counties.

Reference: Wheeler (1916).

14. *Crematogaster laeviuscula clara* Mayr, 1870.
Crematogaster laeviuscula var. *clara*, Verh. Zool.-bot. Ges. Wien, **20**:993, 1870.

This southern species was reported to be present in Indiana by Dr. M. R. Smith. No collection data are known by the writer.

15. *Crematogaster kennedyi* Wheeler, 1930.
Crematogaster kennedyi Wheeler, Psyche, **37**:55-60, 1930.

This is a parasitic species, having no worker caste. It was described from specimens collected by Dr. C. H. Kennedy, September 22, 1929, in Robinson Park, Ft. Wayne, Indiana. The males and females were present in a large colony of *Crematogaster lineolata*.

Genus *Stenamma* Westwood, 1840
Stenamma Westwood, Intr. Class. Ins., 1840.

16. *Stenamma brevicorne* Mayr.

This small brown species is the only one of a typically northern genus known to occur in Indiana. Dr. Mary Talbot, who collected this ant, reports the species subterranean, nesting under wood or stones in rich black soil. They are relatively rare.

Collection Localities: Lake, Parke and Porter counties.

Reference: Talbot (1934).

Genus *Aphaenogaster* Mayr, 1853
Aphaenogaster Mayr, Verh. Zool.-bot. Ges. Wien, **3**:695, 1853.

17. *Aphaenogaster treatae* Forel, 1886.
Aphaenogaster treatae Forel, Comptes-rendus de la Soc. Entom. de Belgique, Seance du six fevrier, 1886.

This beautiful large, dark red ant was collected by Dr. Talbot who reports it comparatively rare and usually confined to sand.

Collection Localities: Lake and Porter counties.

Reference: Talbot (1934).

18. *Aphaenogaster fulva* Roger, 1863.
Aphaenogaster fulva Roger, Berlin Entom. Zeitschr., **7**:190, 1863.

This is a slender, reddish species taken by the writer in the southern part of the state. It nests in the ground and in rotten wood of dense

woods. Although it has a wide distribution, it is common only in localized areas.

Collection Localities: Scott, Tippecanoe and Washington counties.

19. *Aphaenogaster fulva* subsp. *aquia* (Buckley, 1886).
Myrmica (*Monomorium*) *aquia* Buckley, Proc. Ent. Soc. Phila., 26:341, 1886.

A very common ant nesting in rotten wood and under stones.

Collection Localities: Adams, Boone, Clark, Crawford, Delaware, Knox, Lake, Posey, Scott, Tippecanoe and Washington counties.

References: Dennis (1938); Wheeler (1916).

20. *Aphaenogaster fulva aquia picea* Emery, 1894.
Aphaenogaster fulva aquia var. *picea* Emery, Zool. Jahrb. f. Syst., 8:304, 1894.

Merely a color variation of the preceding subspecies. Dr. Talbot found it very common in the Chicago region, usually nesting in well decayed logs.

Collection Localities: Lake, Parke and Porter counties.

Reference: Talbot (1934).

21. *Aphaenogaster texana carolinensis* Wheeler, 1915.
Aphaenogaster texana var. *carolinensis* Wheeler, Bull. Amer. Mus. Nat. Hist., 34:414, 1915.

This is apparently a northern form of a southern species. Blatchley collected the specimens reported from Indiana in 1903 and 1904. It nests both in wood and in the ground.

Collection Localities: Crawford and Lake counties.

22. *Aphaenogaster tennesseensis* Mayr, 1862.
Aphaenogaster tennesseensis Mayr, Verh. Zool.-bot. Ges. Wien, 12:743, 1862.

Another large, beautiful red ant, common in Indiana. The writer found it to nest only in decayed wood, usually at the base of a stump or hollow tree. Wheeler reports, also, that it is a temporary social parasite on *A. fulva*.

Collection Localities: Crawford, Knox, Martin, Scott, Tippecanoe and Washington counties.

Reference: Wheeler (1916).

Genus *Myrmica* Latreille, 1805

Myrmica Latreille, Hist. Nat., 8:258, 1805.

23. *Myrmica scabrinodis brevinodis brevinodis* Emery, 1894.
Myrmica scabrinodis brevinodis Emery, Zool. Jahrb. Syst., 8:312, 1894.

One colony of this species was collected in a corn field in July, 1938. The nest was marked only by a hole in the cultivated surface of the ground.

Collection Locality: Washington County.

24. *Myrmica scabrinodis brevinodis sulcinodoides* Emery, 1894.
Myrmica scabrinodis brevinodis var. *sulcinodoides* Emery, Zool. Jahrb. f. Syst., 8:313, 1894.

This species was collected by Dr. Talbot at Warren's Dunes and Valparaiso in oak-maple woods. She found it only twice, the only records known of this species in the state.
Collection Locality: Porter County.

25. *Myrmica scabrinodis sabuleti* Meinert, 1860.
Myrmica sabuleti Meinert, Naturi. Afg. Dansk. Vid. Selsk., 5:55, 1860.

Reported by Wheeler as a very common ant, nesting in dry open fields and along roads.
Collection Locality: Porter County.
Reference: Wheeler (1916).

26. *Myrmica scabrinodis sabuleti americana* Weber, 1939.
Myrmica sabuleti americana Weber, Lloydia, 2:144-152, 1939.

This variety was taken by Blatchley and the writer also found small colonies in low-ground meadows.
Collection Localities: Lake, Tippecanoe and Washington counties.

27. *Myrmica scabrinodis lobicornis fracticornis* Emery, 1894.
Myrmica rubra scabrinodis fracticornis Emery, Zool. Jahrb. Abth. f. Syst., 8:313, 1894.

Dr. Talbot collected this variety a number of times in Illinois in oak, pasture, roadside and sand flats, but only once in Indiana. The writer collected it singly on a walk in Lake County and found a small colony in a corn field in Washington County.
Collection Localities: Lake, Porter and Washington counties.
Reference: Talbot (1934).

28. *Myrmica scabrinodis schencki emeryana* Forel.

The specimen of this ant collected by the writer was a stray taken on a gravelly river bank. Dr. Talbot reported this variety as numerous in Lake and Porter counties.
Collection Localities: Lake, Porter and Tippecanoe counties.
Reference: Talbot (1934).

Genus *Leptothorax* Mayr, 1855

Leptothorax Mayr, Verh. Zool.-bot. Ges. Wien, 5:431-433, 1855.

29. *Leptothorax fortinodis* Mayr, 1866.
Leptothorax fortinodis Mayr, Verh. Zool.-bot. Ges. Wien, 16:451-452, 1866.

The writer has not taken this species, but one specimen collected by Blatchley in Crawford County, is present in the Purdue University collection.
Collection Locality: Crawford County.

30. *Leptothorax fortinodis melanoticus* Wheeler, 1903.
Leptothorax fortinodis melanoticus Wheeler, Proc. Acad. Nat. Sci. Phila., 55:215-260, 1903.

The writer has never seen this subspecies but it was reported as an Indiana ant by Wheeler.
Collection Localities: Crawford and Marion counties.
Reference: Wheeler (1916).

31. *Leptothorax longispinosus* Roger, 1863.
Leptothorax longispinosus Roger, Berlin Ent. Zeitschr., 7:180, 1863.

Dr. Talbot collected this species nesting under the bark of standing trees. She reports it as rather rare.
Collection Locality: Porter County.
Reference: Talbot (1934).

32. *Leptothorax curvispinosus* Mayr, 1866.
Leptothorax curvispinosus Mayr, Sitz. E. K. Akad. Wiss. Wien, 53:508, 1866.

One of the most common of the *Leptothorax*, this species may be found generally over the state. Wheeler reports it to nest in hollow twigs, galls, nuts and similar places in rather damp, shady woods.
Collection Localities: Fountain, Kosciusko, LaPorte and Rush counties.
Reference: Wheeler (1916).

33. *Leptothorax curvispinosus ambiguus* Emery, 1894.
Leptothorax curvispinosus ambiguus Emery, Zool. Jahrb. f. Syst., 8:320, 1894.

The wrtier has never taken this variety but it is included in Dr. M. R. Smith's list of Indiana ants submitted to Professor J. J. Davis.

34. *Leptothorax* (*Dichothorax*) *pergandei* Emery, 1894.
Leptothorax (*D.*) *pergandei* Emery, Zool. Jahrb. Abth. f. Syst., 8:318-324, 1894.

This species was reported by Wheeler from the state in 1916. Distinctly a southern species, he stated that it was not before known to extend as far north as Indiana.
Collection Locality: Crawford County.
Reference: Wheeler (1916).

Genus *Tetramorium* Mayr, 1855
Tetramorium Mayr, Verh. Zool-bot. Ges. Wien, 5:423, 1855.

35. *Tetramorium caespitum* (Linnaeus), 1768.
Formica caespitum, Linnaeus, Syst. Nat., 12:936, 1768.

Specimens of this robust, dark reddish-brown ant are present in the Purdue University collection from Wayne County. Because of its habit

of nesting under pavements, this ant is sometimes known as the "pavement ant". It has become a serious pest in greenhouses in some localities.

Collection Locality: Wayne County.

Genus *Atta* Fabricius, 1804

Atta Fabricius, Syst. Piezat., p. 421, 1804.

36. *Atta* (*Trachymyrmex*) *septentrionalis obscurior seminole* Wheeler, 1911.

Atta (*Trachymyrmex*) *septentrionalis obscurior seminole* Wheeler, Jr. N.Y. Ent. Soc., **19**:247, 1911.

This medium sized light brown ant is distinctive because of its rough spine and tubercle-bearing integument.

This species was reported as occurring in Indiana by M. R. Smith. No collection locality or data are given. Dennis (1938) reports this ant to be very common in Tennessee in moist, densely shady localities of some regions. It is a southern ant which requires a high temperature and plenty of moisture for the raising of fungus which is its only food. It is slow moving and timid, hiding under leaves and particles of dirt when disturbed.

Subfamily Dolichoderinae

The members of the Dolichoderinae often possess anal glands which produce a secretion having a peculiar rancid butter-like odor.

Genus *Dolichoderus* Lund, 1831

Dolichoderus Lund, Ann. Sci. Nat., **25**:130, 1831.

37. *Dolichoderus mariae* Forel, 1884.

Dolichoderus mariae Forel, Bull. Soc. Vaud. Sci. Nat., **20**:349, 1884.

Three specimens of this ant with a bright yellowish-red head and thorax were collected by W. S. Blatchley and are present in the Purdue University collection. This is probably the most beautiful of all our ants. It forms large colonies, nesting in sandy places about the roots of plants, the workers ascending trees in files to attend aphids and coccids.

Collection Locality: Lake County.

Reference: Wheeler (1905).

38. *Dolichoderus mariae blatchleyi* Wheeler, 1916.

Dolichoderus mariae var. *blatchleyi* Wheeler, Proc. Ind. Acad. Sci., **26**:462, 1916.

This variety was described from Indiana specimens.

Collection Localities: Lake and Starke counties.

Reference: Wheeler (1916).

39. *Dolichoderus plagiatus pustulatus beutenmulleri* Wheeler, 1904.

Dolichoderus plagiatus Mayr var. *beutenmulleri* Wheeler, Bull. Amer. Mus., **20**:304, 1904.

An ant listed by Wheeler in 1916. He reports it to nest in the ground, forming rather small colonies.

Collection Locality: Lake County.

Reference: Wheeler (1916).

Genus *Dorymyrmex* Mayr, 1866

Dorymyrmex Mayr, Sitz. Akad. Wiss. Wien, 53:494, 1866.

40. *Dorymyrmex pyramicus* Roger, 1863.

Dorymyrmex pyramicus Roger, Berlin Ent. Zeitschr., 7:160, 1863.

D. pyramicus was reported as an Indiana ant by M. R. Smith in 1937. No collection or other data are known to the writer. This species, commonly called the "Lion ant", nests in sunny places and builds a small crater about the opening of its nest.

Reference: Dennis (1938).

Genus *Tapinoma* Forster, 1850

Tapinoma Forster, Hym. Stud., 1:43, 1850.

41. *Tapinoma sessile* (Say, 1836).

Formica sessilis Say, Boston Jour. Nat. Hist., 1:287, 1836.

A very common household pest, *T. sessile* nests under stones and boards in dry, sunny places. Because of the unpleasant, nauseating, tapinoma-like odor it produces it is known as the "tapinoma" ant.

Collection Localities: Fulton, Lake, Marion, Starke and Tippecanoe counties.

References: Dennis (1938); Wheeler (1916).

Genus *Iridomyrmex* Mayr, 1862

Iridomyrmex Mayr, Verh. Zool.-bot. Ges. Wien, 12:702, 1862.

42. *Iridomyrmex pruinosus* Roger, 1863.

Iridomyrmex pruinosus Roger, Berlin Ent. Zeitschr., 7:165, 1863.

This small, light brown, slender species was taken once from a ground nest in an open unplowed field near Salem. The ant is listed from a few southern states, but as far as the writer can ascertain, it is not recorded north of Indiana.

Collection Locality: Washington County.

43. *Iridomyrmex pruinosus analis* Andre, 1893.

Iridomyrmex pruinosus var. *analis* Andre, Rev. Ent., p. 148, 1893.

Dennis (1938) reports this ant to be the most abundant ant of the sandy region of western Tennessee. It was taken only once in Indiana.

Collection Locality: Daviess County.

Reference: Dennis (1938).

Subfamily Camponotinae

This subfamily includes more than half of the species, subspecies and varieties of ants known to occur in Indiana. They, of course, are more highly developed than the preceding subfamilies and include the

true slave-making species which "sally forth on predatory expeditions for the purpose of procuring slaves they employ in their domestic business".[3]

Genus *Brachymyrmex* Mayr, 1868

Brachymyrmex Mayr, Ann. Soc. Nat. Mod., 3:163, 1868.

44. *Brachymyrmex heeri depilis* Emery, 1893.
Brachymyrmex heeri subsp. *depilis* Emery, Zool. Jahrb. f. Syst., 7:635, 1893.

This is the tiniest of our Indiana ants, measuring only 1.25 to 1.75 mm. in length. The writer took this species only once, nesting under moss in dense woods.

Collection Localities: Knox and Washington counties.

Reference: Wheeler (1916).

Genus *Prenolepis* Mayr, 1861

Prenolepis Mayr, Eur. Form., 52, 1861.

45. *Prenolepis imparis* (Say, 1836).
Formica imparis Say, Boston Jour. Nat. Hist., 1:287, 1836.

Dr. Wheeler listed this species in 1916 as one not previously recorded in the state but one undoubtedly occurring in Indiana. The writer found it to be very common in clay soil. It is known as the "honey ant."

Collection Localities: Crawford, Kosciusko, Tippecanoe and Washington counties.

Reference: Wheeler (1916).

46. *Prenolepis imparis minuta* Emery, 1893.
Prenolepis imparis var. *minuta* Emery, Zool. Jahrb. Abth. Syst., 7:636, 1893.

Closely resembling the typical species but decidedly smaller. The author found it to be less common than *P. imparis*.

Collection Localities: Crawford, Lake, Tippecanoe and Washington counties.

Reference: Wheeler (1916), (1930).

47. *Prenolepis imparis pumila* Wheeler, 1930.
Prenolepis imparis var. *pumila* Wheeler, Ann. Ent. Soc. Amer., 23:21, 1930.

This tiny ant bears the same relation to the variety *testacea* as the variety *minuta* bears to the typical *P. imparis*. It was first taken in Indiana by Dr. B. E. Montgomery from black locust in 1937.

Collection Locality: Clark County.

Reference: Wheeler (1930).

Genus *Paratrechina* Mots., 1863

Paratrechina Motschoulsky, Bull. Mosc. Soc. Nat., 2:11, 1863.

[3] Kirby and Spence, Entomology 6th ed., 1846.

48. *Paratrechina* (*Nylanderia*) *parvula* (Mayr, 1870).
Prenolepis parvula Mayr, Verh. Zool.-bot. Ges. Wien, 20:948, 1870.

This ant was taken only twice by the writer, each time from a ground nest in a gravelly hillside. Dennis (1938) states that next to *Lasius niger americana*, this species is the most common ant in Tennessee.

Collection Localities: Lake (Wheeler 1916), Tippecanoe and Washington counties.

References: Dennis (1938); Wheeler (1916).

49. *Paratrechina* (*Nylanderia*) *longicornis* (Latreille, 1802).
Formica longicornis Latreille, Hist. Nat., 113, 1802.

P. longicornis is easily identified by its extraordinarily long antennae and legs. Dr. M. R. Smith informs the writer that he has examined specimens taken in Indianapolis by Harry F. Dietz.

Collection Locality: Marion County.

Genus *Lasius* Fabricius, 1804

Lasius Fabricius, Syst. Piez., 415, 1804.

50. *Lasius niger neoniger* Emery, 1893.
Lasius niger var. *neoniger* Emery, Zool. Jahrb. f. Syst., 7:639, 1893.

This common ant was always found nesting in the ground.

Collection Localities: Benton, Lake, Martin, Rush, Tippecanoe and Washington counties.

Reference: Wheeler (1916).

51. *Lasius niger americanus* (Linnaeus, 1758).
Formica nigra Linn., Syst. Nat., Ed. 10a, 1:580, 1758.

This ant is more common than any other found in the state and is probably our most important economic pest found among ants. It has been proven responsible for the spread of the corn root louse, *Aphis maidi-radiois*.

Collection Localities: Crawford, Daviess, Fountain, Jackson, Jennings, Knox, Kosciusko, Lake, Parke, Posey, Tippecanoe and Washington counties.

References: Dennis (1938); Talbot (1934); Wheeler (1916).

52. *Lasius umbratus minutus* Emery, 1893.
Lasius umbratus var. *minutus* Emery, Zool. Jahrb. f. Syst., 7:637, 1893.

Messrs. P. T. Ulman and A. W. Trippel collected this ant from a sphagnum bog in Steuben County in June, 1942. The colony had formed a flat-topped mound of some three feet in diameter and about 18 inches in height. It was well shaded, largely by ash, tamarack and sumac. Dr. Smith informs me that apparently *minutus* nests largely, if not exclusively, in bog-like areas where the soil is acid.

Collection Locality: Steuben County.

53. *Lasius umbratus mixtus aphidicola* (Walsh, 1862).
Formica mixta var. *aphidicola* Walsh, Proc. Ent. Soc. Phila., 2:310, 1862.

This medium-sized yellow ant resembles the "citronella" ants superficially. It nests in logs or stumps, or in the ground in damp, shady woods. Wheeler (1916) included it as a probable Indiana species.
Collection Localities: Clinton and Tippecanoe counties.
Reference: Wheeler (1916).

54. *Lasius* (*Acanthomyops*) *interjectus* Mayr, 1886.
Lasius interjectus Mayr, Verh. Zool.-bot. Ges. Wien, **16**:886, 1886.

A very common ant in Indiana, nesting in the ground or in logs in rather damp situations.
Collection Localities: Fayette, Lake, Rush, Tippecanoe and Washington counties.

55. *Lasius* (*Acanthomyops*) *claviger* (Roger, 1862).
Formica claviger Roger, Berlin Ent. Zeitschr., 6:241, 1862.

One of our most common species with habits similar to *interjectus*. Both species have a rather pleasant odor, like that of oil of citronella or lemon-verbena, and for this reason are called the "citronella" ants.
Collection Localities: Clinton, Fulton, Hancock, Knox, Miami, Starke, Tippecanoe, Tipton and Washington counties.
Reference: Wheeler (1916).

56. *Lasius* (*Acanthomyops*) *latipes* (Walsh, 1864).
Formica latipes Walsh, Proc. Ent. Soc. Phila., 4:311, 1864.

Wheeler listed this as an Indiana species from the following county.
Collection Locality: Fulton County.
Reference: Wheeler (1916).

Genus *Formica* Linnaeus, 1767
Formica Linnaeus, Syst. Nat., 2:962, 1767.

The largest and one of the most important genera found within the boundaries of the state. More than one-fourth of Indiana's total number of known species belong to this genus.

57. *Formica sanguinea aserva* Forel, 1901.
Formica sanguinea aserva Forel, Ann. Soc. Ent. Belg., 45:395, 1901.

Miss Talbot collected this ant at the edge of an oak-maple woods.
Collection Locality: Porter County.
Reference: Talbot (1934).

58. *Formica sanguinea rubricunda* Emery, 1893.
Formica sanguinea subsp. *rubricunda* Emery, Zool. Jahrb. f. Syst., 7:647, 1893.

Dr. Smith listed *rubricunda* as an Indiana ant in his list of Indiana ants in 1937. No collection data are known to the writer. Like all *sanguinea*, it is a true slave-maker, establishing colonies by kidnapping and rearing pupae of *F. fusca subsericea*.

Reference: Wheeler (1915).

59. *Formica sanguinea subintegra* Emery, 1893.
Formica sanguinea rubricunda var. *subintegra* Emery, Zool. Jahrb. f. Syst., **7**:648, 1893.

This ant was also listed from Indiana by Dr. Smith.

60. *Formica sanguinea puberla* Emery, 1893.
Formica sanguinea puberla Emery, Zool. Jahrb. f. Syst., 7:648, 1893.

A new subspecies to the list of Indiana ants taken by Dr. H. O. Deay in a corn field in 1937. Distinctly a western ant, Indiana probably marks the limit of its distribution.

Collection Locality: Lake County.

61. *Formica rufa aggerans melanotica* Emery, 1893.
Formica rufa obscuriventris var. *melanotica* Emery, Zool. Jahr. f. Syst., **7**:644, 1893.

This ant is also listed by Dr. M. R. Smith as from Indiana.

62. *Formica truncicola integra* Nylander, 1856.
Formica integra Nylander, Ann. Sci. Nat. Zool., **5**:62, 1856.

A large red and black ant living in huge colonies in rather rich, open woods or hilly regions. The workers are very vicious when aroused. It was reported in Indiana by Wheeler.

Collection Localities: Crawford and Perry counties.

References: Wheeler (1915, 1916).

63. *Formica truncicola obscuriventris* Mayr, 1870.
Formica truncicola var. *obscuriventris* Mayr, Verh. Zool.-bot. Ges. Wien, **20**:931, 1870.

An eastern species listed by Wheeler in 1916.

Collection Locality: Kosciusko County.

Reference: Wheeler (1916).

64. *Formica dakotensis* Emery, 1893.
Formica dakotensis Emery, Zool. Jahrb. f. Syst., **7**:652, 1893.

This species is reported as an Indiana ant by M. R. Smith.

Reference: Wheeler (1915).

65. *Formica postoculata* Kennedy and Dennis, 1937.
Formica postoculata Kennedy and Dennis, Ann. Ent. Soc. Amer., **30**:540, 1937.

This ant was described from specimens collected by the senior author and Arthur C. Cole, Jr., in Ohio County.

Reference: Kennedy and Dennis (1937).

66. *Formica querquetulana* Kennedy and Dennis, 1937.
Formica querquetulana Kennedy and Dennis, Ann. Ent. Soc. Amer., **30**:536, 1937.

Although described from specimens collected in Ohio, this ant has been taken by Dr. Kennedy and Dr. Talbot in Spencer County.
Reference: Kennedy and Dennis (1937).

67. *Formica exsectoides* Forel, 1886.
Formica exsectoides Forel, Ann. Soc. Ent. Belg., **30**:38, 1886.

This beautiful red and black "mound-building ant of the Alleghenies," although not abundant in Indiana, is taken occasionally. It is very fierce and attacks furiously any intruder on its preserves and kills other ants by decapitating them.
Collection Localities: Clark, Morgan and Vigo counties.
Reference: Wheeler (1915).

68. *Formica ulkei* Emery, 1893.
Formica ulkei Emery, Zool. Jahrb. f. Syst., **7**:653, 1893.

A species with habits similar to the preceding species. It was reported as an Indiana ant by Wheeler.
Collection Locality: Kosciusko County.
Reference: Wheeler (1916).

69. *Formica ulkei hebescens* Wheeler, 1913.
Formica ulkei var. *hebescens* Wheeler, Bull. Mus. Comp. Zool., **53**:487, 1913.

Indiana is the type locality for this variety which was described from specimens collected by W. S. Blatchley at Bass Lake.
Collection Locality: Starke County.
References: Wheeler (1915, 1916).

70. *Formica fusca* Linn., 1758.
Formica fusca Linn., Syst. Nat., **1**:580, ed. 10, 1758.

No collection locality is known to the writer but this species is listed as an Indiana ant by M. R. Smith.
In habits, members of this group are extremely timid, which make them ideal hosts for a large number of *Formica* of the *sanguinea*, *rufa*, *microgyna* and *exsecta* group.
Reference: Wheeler (1915).

71. *Formica fusca subsericea* Say, 1836.
Formica subsericea Say, Bost. Jour. Nat. Hist., **1**:289, 1836.

Probably the most common ant found in Indiana, excepting *Lasius niger americana* Emery. It nests in sunny places under stones or in low flat mounds.
Collection Localities: Clark, Crawford, Fountain, Kosciusko, Lake, Marshall, Martin, Perry, Rush, Starke, St. Joseph, Tippecanoe and Washington counties.
Reference: Wheeler (1913, 1916).

72. *Formica fusca argentata* Wheeler, 1902.
Formica fusca var. *argentata* Wheeler, Amer. Nat., 36:952, 1902.

A variety not recorded by Wheeler nor taken by the writer but specimens from Indiana are present in the Purdue University collection.
Collection Localities: Morgan and Tippecanoe counties.

73. *Formica fusca subaenescens* Emery, 1893.
Formica fusca var. *subaenescens* Emery, Zool. Jahrb. f. Syst., 7:659, 1893.

An ant closely related to the preceding variety. *F. subaenescens* was taken by Miss Talbot in 1933.
Collection Locality: Porter County.
Reference: Wheeler (1915).

74. *Formica cinerea neocinerea* Wheeler, 1902.
Formica cinerea var. *neocinerea* Wheeler, Amer. Nat., 36:947, 1902.

This ant was listed by Wheeler (1916), who suggested Indiana to be the probable eastern limit of the species' distribution.
Collection Locality: LaPorte County.
Reference: Wheeler (1916).

75. *Formica neogagates* Emery, 1893.
Formica fusca subpolita var. *neogagates* Emery, Zool. Jahrb. f. Syst., 7:661, 1893.

This relatively small red and black *Formica* was listed by Wheeler (1916) and also taken by Dr. H. O. Deay in a corn field of Lake County.
It is a highland form, usually nesting in rather small colonies, under stones or in obscure craters.
Collection Localities: Lake and Kosciusko counties.
References: Wheeler (1915, 1916).

76. *Formica pallide-fulva schaufussi* Mayr, 1866.
Formica schaufussi Mayr, Sitz. K. Akad. Wiss. Wien, 53:493, 1866.

Referred to as "one of our commonest ants" by Wheeler (1916), the author failed to take any of this species. It is reported to have nesting habits similar to the preceding variety.
Collection Localities: Crawford, Martin, Posey and St. Joseph counties.
References: Wheeler (1915, 1916).

77. *Formica pallide-fulva schaufussi incerta* Emery, 1893.
Formica pallide-fulva schaufussi var. *incerta* Emery, Zool. Jahr. f. Syst., 7:655, 1893.

Although not abundant, this variety was taken several times in open situations.
Collection Localities: Clark, Crawford, Martin, Tippecanoe and Washington counties.
Reference: Wheeler (1915).

78. *Formica pallide-fulva nitidiventris* Emery, 1893.
Formica pallide-fulva nitidiventris Emery, Zool. Jahr. f. Syst., 7:656, 1893.

This subspecies was taken by the writer from ground nests located in a dense woods. It was also reported by Wheeler in 1916.

Collection Localities: Kosciusko, Lake, LaPorte, Martin and Washington counties.

References: Wheeler (1915, 1916).

79. *Formica pallide-fulva nitidiventris fuscata* Emery, 1893.
Formica pallide-fulva subsp. *fuscata* Emery, Zool. Jahr. f. Syst., 7:656, 1893.

A variety, deeper in coloration than the typical form. It was collected by Dr. H. O. Deay in Lake County. Wheeler (1915) reports it to be much rarer than any of the other varieties or subspecies of the *pallide-fulva* group.

Collection Locality: Lake County.

Reference: Wheeler (1915).

Genus *Polyergus* Latreille, 1805

Polyergus Latreille, Hist. Nat., 8:256, 1805.

80. *Polyergus rufenscens breviceps* Emery.

This is a beautiful, large, light red ant with a shining gaster. It was taken by W. S. Blatchley from Crawford County.

81. *Polyergus lucidus* Mayr, 1870.
Polyergus lucidus Mayr, Verh. Zool.-bot. Ges. Wien, **20**:952, 1870.

This species was reported from Indiana by Wheeler in 1916. This and the preceding species are obligatory slavemakers and are commonly called "amazons." *P. lucidus* is MacCook's "shining slavemaker."

The workers of this group are extremely pugnacious and their mouthparts are so constructed so that they are unable to excavate their own nests or care for their young and thus are entirely dependent on their slaves. On their predatory expeditions, however, they display dazzling courage and a capacity for concerted action perhaps unrivaled in the insect world.

Collection Locality: St. Joseph County.

Reference: Wheeler (1916).

Genus *Camponotus* Mayr, 1861

Camponotus Mayr, Eur. Form., 35, 1861.

82. *Camponotus castaneus* Latreille, 1802.
Camponotus castaneus Latreille, Hist. Nat., 1802.

A large yellowish or reddish-brown species nesting under stones. It is common in Indiana.

Collection Localities: Crawford, Harrison, Knox, Lake, Lawrence. Perry, Posey, Scott, St. Joseph, Tippecanoe and Warren counties.

Reference: Wheeler (1916).

83. *Camponotus castaneus americanus* Mayr, 1862.
Camponotus castaneus subsp. *americana* Mayr, Verh. Zool.-bot. Ges. Wien, 12:661, 1862.

Although reported to have habits similar to the typical variety, the writer found this species more often under loose bark of dead trees than in the ground.

Collection Localities: Clark, Crawford, Lake, Lawrence and Washington counties.

Reference: Wheeler (1916).

84. *Camponotus herculeanus pennsylvanicus* (DeGeer, 1773).
Formica pennsylvanica DeGeer, Mem. Serv. Hist. Insects, 3:603, 1773.

One of the largest of our Indiana ants, this "carpenter ant" usually nests in wood. It is a common household pest, taking up its residence in homes and causing damage to wood work and it also visits kitchens in search of sweets.

Collection Localties: Clark, Crawford, Fulton, Greene, Henry, Howard, Knox, Kosciusko, Lake, LaPorte, Lawrence, Marshall, Posey, Rush, Starke, Tippecanoe and Washington counties.

References: Wheeler (1910, 1916).

85. *Camponotus herculeanus pennsylvanicus ferrugineus* (Fabricius, 1798).
Formica ferruginea Fabricius, Supplt. Entom. Syst., p. 279, 1798.

A less abundant color variation of the typical form.

Collection Localities: Crawford, Knox, Lake, Lawrence, Posey, Tippecanoe and Washington counties.

Reference: Wheeler (1916).

86. *Camponotus herculeanus ligniperda noveboracensis* Fitch, 1854.
Formica noveboracensis Fitch, Trans. N. Y. State Agr. Soc., 14:52, 1854.

This variety differs from the preceding *herculeanus* varieties in color and size. It was reported in Indiana by Wheeler (1916).

Collection Localities: Kosciusko, Lake and St. Joseph counties.

Reference: Wheeler (1916).

87. *Camponotus caryae* (Fitch, 1855).
Formica caryae Fitch, Trans. N. Y. State Agr. Soc., 14:855-859, 1855.

This ant is relatively common, nesting in dead branches.

Collection Localities: Clark, Crawford and Washington counties.

Reference: Wheeler (1916).

88. *Camponotus caryae minutus* Emery, 1893.
Camponotus marginatus var. *minutus* Emery, Zool. Jahr. Abth. f. Syst., 7:676, 1893.

Wheeler cited this species in his "List of Indiana Ants" in 1916.
Collection Localities: Posey and Perry countes.
Reference: Wheeler (1916).

89. *Camponotus caryae decipiens* Emery, 1893.
Camponotus marginatus var. *decipiens* Emery, Zool. Jahr. Abth. f. Syst., 7:676, 1893.

Although Indiana is the type locality for this variety, described from specimens received from Mr. Theodore Pergande, Wheeler (1916) does not list the collection locality.
Reference: Wheeler (1916).

90. *Camponotus caryae subbarbatus* Emery, 1893.
Camponotus marginatus subsp. *subbarbatus* Emery, Zool. Jahr. Abth. f. Syst., 7:678, 1893.

A beautiful variety, easily distinguished from the remaining *caryae* found to occur in Indiana by its brownish-yellow head and thorax and broad transverse brown bands on the gaster, interspaced with lighter brown or yellow. This ant was taken by Dr. Talbot in Turkey Run Park. It is reported to be rare.
Collection Locality: Parke County.
Reference: Wheeler (1910).

91. *Camponotus caryae discolor* (Buckley, 1866).
Formica discolor Buckley, Proc. Ent. Soc. Phila., 6:166, 1866.

Dr. Talbot collected stray ants of this variety on two occasions.
Collection Locality: Porter County.
Reference: Talbot (1934).

92. *Camponotus caryae cnemidatus* Emery.
The writer has never seen a specimen of this ant. It is listed as an Indiana ant by Dr. M. R. Smith. No collection data are known to the writer.

Members of the Formicidae which have not been recorded from Indiana but which are probably present in the state are as follows:

1. *Ponera gilva* Roger
2. *Proceratium croceum* Roger
3. *Ponera trigona opacior* Forel
4. *Eciton* (*Acamatus*) *opacithorax* Emery
5. *Pheidole dentata* Mayr
6. *Pheidole tysoni* Forel
7. *Pheidole vinelandica* Forel
8. *Pheidole vinelandica laeviuscula* Emery
9. *Pheidole anastasii* Emery

10. *Crematogaster laeviuscula* Mayr
11. *Crematogaster victima missouriensis* Wheeler
12. *Stenamma brevicorne diecki* Emery
13. *Stenamma brevicorne impar* Forel
14. *Stenamma brevicorne schmitti* Wheeler
15. *Aphaenogaster subterranea occidentalis* Emery
16. *Aphaenogaster mariae* Forel
17. *Aphaenogaster lamellidens* Mayr
18. *Aphaenogaster fulva aquia ridis* Emery
19. *Pogonomyrmex occidentalis* Cresson
20. *Mrymica punctiventris* Roger
21. *Mrymica punctiventris pinetorum* Wheeler
22. *Mrymica scabrinodis schencki* Emery
23. *Leptothorax acervorum canadensis* Provancher
24. *Leptothorax schaumi* Roger
25. *Leptothorax texanus* Wheeler
26. *Leptothorax* (*D.*) *pergandei floridanus* Emery
27. *Tetramorium guineense* Fabr.
28. *Strumigenys pergandei* Emery
29. *Strumigenys pulchella* Emery
30. *Strumigenys dietrichi* Smith
31. *Strumigenys ohioensis* Kenn. & Schramm
32. *Dolichoderus taschenbergi* Mayr
33. *Dolichoderus plagiatus* Mayr
34. *Dolichoderus plagiatus inornata* Wheeler
35. *Dolichoderus plagiatus pustulatus* Mayr
36. *Dorymyrmex pyramicus flavus* Pergande
37. *Tapinoma pruinosum* Roger
38. *Iridomyrmex humilis* Mayr
39. *Prenolepsis imparis testacea* Emery
40. *Paratrechina vividula quatemalensis* Forel
41. *Lasius brevicornis* Emery
42. *Lasius flavus nearcticus* Wheeler
43. *Lasius umbratus speculiventris* Emery
44. *Lasius murphyi* Forel
45. *Formica pergandei* Emery
46. *Formica sanguinea subnuda* Emery
47. *Formica adamsi* Wheeler
48. *Formica truncicola gymnomma* Wheeler
49. *Formica truncicola melanotica* Emery
50. *Formica difficilis* Emery
51. *Formica neogagates lasioides vetula* Wheeler
52. *Formica perpilosa* Wheeler
53. *Polyergus rufescens bicolor* Wasmann
54. *Polyergus rufescens foreli* Wheeler
55. *Camponotus herculeanus pennsylvanicus rubens* Wheeler
56. *Camponotus caryae tanquaryi* Wheeler

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